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PROCEEDINGS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

VOL. XII.

PAPERS READ BEFORE THE ACADEMY.

I.

RESEARCHES IN TELEPHONY.

By A. Graham Bell.

Presented May 10, 1876, by the Corresponding Secretary.

1. It has long been known that an electro-magnet gives forth a decided sound when it is suddenly magnetized or demagnetized. When the circuit upon which it is placed is rapidly made and broken, a succession of explosive noises proceeds from the magnet. These sounds produce upon the ear the effect of a musical note, when the current is interrupted a sufficient number of times per second. The discovery of "Galvanic Music," by Page,* in 1837, led inquirers in different parts of the world almost simultaneously to enter into the field of telephonic research; and the acoustical effects produced by magnetization were carefully studied by Marrian,† Beatson,‡ Gassiot,§ De la Rive,‖

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* *C. G. Page.* "The Production of Galvanic Music." Silliman's Journ., 1837, XXXII., p. 396; Silliman's Journ., July, 1837, p. 354; Silliman's Journ., 1838, XXXIII., p. 118; Bibl Univ. (new series), 1839, II., p. 398.

† *J. P. Marrian.* Phil. Mag., XXV., p. 382; Inst., 1845, p. 20; Arch. de l'Électr., V., p. 195.

‡ *W. Beatson.* Arch. de l'Électr., V., p. 197; Arch. de Sc. Phys. et Nat. (2d series), II., p. 113.

§ *Gassiot.* See "Treatise on Electricity," by De la Rive, I., p. 300.

‖ *De la Rive.* Treatise on Electricity, I., p. 300; Phil. Mag., XXXV., p. 422; Arch. de l'Électr., V., p 200; Inst., 1846, p. 83; Comptes Rendus, XX., p. 1287; Comp. Rend., XXII., p. 432; Pogg. Ann., LXXVI., p. 637; Ann. de Chim. et de Phys., XXVI., p. 158.

Matteucci,* Guillemin,† Wertheim,‡ Wartmann,§ Janniar,‖ Joule,¶ Laborde,** Legat,†† Reis,‡‡ Poggendorff,§§ Du Moncel,‖‖ Delezenne,¶¶ and others.***

2. In the autumn of 1874, I discovered that the sounds emitted by an electro-magnet under the influence of a discontinuous current of electricity are not due wholly to sudden changes in the magnetic condition of the iron core (as heretofore supposed), but that a portion of the effect results from vibrations in the insulated copper-wires composing the coils. An electro-magnet was arranged upon circuit with an instrument for interrupting the current, — the rheotome being placed in a distant room, so as to avoid interference with the experiment. Upon applying the ear to the magnet, a musical note was clearly perceived, and the sound persisted after the iron core had been removed. It was then much feebler in intensity, but was otherwise unchanged, — the curious crackling noise accompanying the sound being well marked.

The effect may probably be explained by the attraction of the coils of the wire for one another during the passage of the galvanic current,

* *Matteucci.* Inst., 1845, p. 315; Arch. de l'Électr., V., 389.

† *Guillemin.* Comp. Rend., XXII., p. 264; Inst., 1846, p. 30; Arch. d. Sc. Phys. (2d series), I., p. 191.

‡ *G. Wertheim.* Comp. Rend., XXII., pp. 336, 544; Inst., 1846, pp. 65, 100; Pogg. Ann., LXVIII, p. 140; Comp. Rend., XXVI., p. 505; Inst., 1848, p. 142; Ann. de Chim. et de Phys., XXIII., p. 302; Arch. d. Sc. Phys. et Nat., VIII., p. 206; Pogg. Ann., LXXVII., p. 43; Berl. Ber., IV., p. 121.

§ *Elie Wartmann.* Comp. Rend., XXII., p. 544; Phil. Mag. (3d series), XXVIII., p. 544; Arch. d. Sc. Phys. et Nat. (2d series), I., p. 419; Inst., 1846, p. 290; Monatscher. d. Berl. Akad., 1846, p. 111.

‖ *Janniar.* Comp. Rend., XXIII., p. 319; Inst., 1846, p. 269; Arch. d. Sc. Phys. et Nat. (2d series), II., p. 394.

¶ *J. P. Joule.* Phil. Mag., XXV., pp. 76, 225; Berl. Ber., III., p. 489.

** *Laborde.* Comp. Rend., L., p. 692; Cosmos, XVII., p. 514.

†† *Legat.* Brix. Z. S., IX., p. 125.

‡‡ *Reis.* "Téléphonie." Polytechnic Journ., CLXVIII., p. 185; Böttger's Notizbl., 1863, No. 6.

§§ *J. C. Poggendorff.* Pogg. Ann., XCVIII., p. 192; Berliner Monatsber., 1856, p. 133; Cosmos, IX., p. 49; Berl. Ber., XII., p. 241; Pogg. Ann., LXXXVII., p. 139.

‖‖ *Du Moncel.* Exposé, II., p. 125; also, III., p. 83.

¶¶ *Delezenne.* "Sound produced by Magnetization," Bibl. Univ. (new series), 1841, XVI., p. 406.

*** See London Journ., XXXII., p. 402; Polytechnic Journ., CX., p. 16; Cosmos, IV., p. 43; Glösener —— Traité général, &c., p. 350; Dove.-Repert., VI., p. 58; Pogg. Ann., XLIII., p. 411; Berl. Ber., I., p. 144; Arch. d. Sc. Phys. et Nat., XVI., p. 406; Kuhn's Encyclopædia der Physik, pp. 1014–1021.

and the sudden cessation of such attraction when the current is interrupted. When a spiral of fine wire is made to dip into a cup of mercury, so as thereby to close a galvanic circuit, it is well known that the spiral coils up and shortens. Ferguson * constructed a rheotome upon this principle. The shortening of the spiral lifted the end of the wire out of the mercury, thus opening the circuit, and the weight of the wire sufficed to bring the end down again, — so that the spiral was thrown into continuous vibration. I conceive that a somewhat similar motion is occasioned in a helix of wire by the passage of a discontinuous current, although further research has convinced me that other causes also conspire to produce the effect noted above. The extra currents occasioned by the induction of the voltaic current upon itself in the coils of the helix no doubt play an important part in the production of the sound, as very curious audible effects are produced by electrical impulses of high tension. It is probable, too, that a molecular vibration is occasioned in the conducting wire, as sounds are emitted by many substances when a discontinuous current is passed through them. Very distinct sounds proceed from straight pieces of iron, steel, retort-carbon, and plumbago. I believe that I have also obtained audible effects from thin platinum and German-silver wires, and from mercury contained in a narrow groove about four feet long. In these cases, however, the sounds were so faint and outside noises so loud that the experiments require verification. Well-marked sounds proceed from conductors of all kinds when formed into spirals or helices. I find that De la Rive had noticed the production of sound from iron and steel during the passage of an intermittent current, although he failed to obtain audible results from other substances. In order that such effects should be observed, extreme quietness is necessary. The rheotome itself is a great source of annoyance, as it always produces a sound of similar pitch to the one which it is desired to hear. It is absolutely requisite that it should be placed out of earshot of the observer, and at such a distance as to exclude the possibility of sounds being mechanically conducted along the wire.

3. Very striking audible effects can be produced upon a short circuit by means of two Grove elements. I had a helix of insulated copper-wire (No. 23) constructed, having a resistance of about twelve ohms. It was placed in circuit with a rheotome which interrupted the current one hundred times per second. Upon placing the helix to my ear I

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* *Ferguson.* Proceedings of Royal Scottish Soc. of Arts, April 9, 1866; Paper on "A New Current Interrupter."

could hear the unison of the note produced by the rheotome. The intensity of the sound was much increased by placing a wrought-iron nail inside the helix. In both these cases, a crackling effect accompanied the sound. When the nail was held in the fingers so that no portion of it touched the helix, the crackling effect disappeared, and a pure musical note resulted.

When the nail was placed inside the helix, between two cylindrical pieces of iron, a loud sound resulted that could be heard all over a large room. The nail seemed to vibrate bodily, striking the cylindrical pieces of metal alternately, and the iron cylinders themselves were violently agitated.

4. Loud sounds are emitted by pieces of iron and steel when subjected to the attraction of an electro-magnet which is placed in circuit with a rheotome. Under such circumstances, the armatures of Morse-sounders and Relays produce sonorous effects. I have succeeded in rendering the sounds audible to large audiences by interposing a tense membrane between the electro-magnet and its armature. The armature in this case consisted of a piece of clock-spring glued to the membrane. This form of apparatus I have found invaluable in all my experiments. The instrument was connected with a parlor organ, the reeds of which were so arranged as to open and close the circuit during their vibration. When the organ was played the music was loudly reproduced by the telephonic receiver in a distant room. When chords were played upon the organ, the various notes composing the chords were emitted simultaneously by the armature of the receiver.

5. The simultaneous production of musical notes of different pitch by the electric current, was foreseen by me as early as 1870, and demonstrated during the year 1873. Elisha Gray,* of Chicago, and Paul La Cour,† of Copenhagen, lay claim to the same discovery. The fact that sounds of different pitch can be simultaneously produced upon any part of a telegraphic circuit is of great practical importance; for the duration of a musical note can be made to signify the dot or dash of the Morse alphabet, and thus a number of telegraphic messages may be sent simultaneously over the same wire without confusion by making signals of a definite pitch for each message.

6. If the armature of an electro-magnet has a definite rate of oscillation of its own, it is thrown bodily into vibration when the interrup-

* *Elisha Gray.* Eng. Pat. Spec., No. 974. See "Engineer," March 26, 1875.
† *Paul la Cour.* Telegraphic Journal, Nov. 1, 1875.

tions of the current are timed to its movements. For instance, present an electro-magnet to the strings of a piano. It will be found that the string which is in unison with the rheotome included in the circuit will be thrown into vibration by the attraction of the magnet.

Helmholtz,* in his experiments upon the synthesis of vowel sounds caused continuous vibration in tuning-forks which were used as the armatures of electro-magnets. One of the forks was employed as a rheotome. Platinum wires attached to the prongs dipped into mercury.

The intermittent current occasioned by the vibration of the fork traversed a circuit containing a number of electro-magnets between the poles of which were placed tuning-forks whose normal rates of vibration were multiples of that of the transmitting fork. All the forks were kept in continuous vibration by the passage of the interrupted current. By re-enforcing the tones of the forks in different degrees by means of resonators, Helmholtz succeeded in reproducing artificially certain vowel sounds.

I have caused intense vibration in a steel strip, one extremity of which was firmly clamped to the pole of a U-shaped electro-magnet, the free end overhanging the other pole. The amplitude of the vibration was greatest when the coil was removed from the leg of the magnet to which the armature was attached.

7. All the effects noted above result from rapid interruptions of a voltaic current, but sounds may be produced electrically in many other ways.

The Canon Gottoin de Coma,† in 1785, observed that noises were emitted by iron rods placed in the open air during certain electrical conditions of the atmosphere; Beatson ‡ produced a sound from an iron wire by the discharge of a Leyden jar; Gore § obtained loud musical notes from mercury, accompanied by singularly beautiful crispations of the surface during the course of experiments in electrolysis; and Page ‖ produced musical tones from Trevelyan's bars by the action of the galvanic current.

8. When an intermittent current is passed through the thick wires of a Ruhmkorff's coil, very curious audible effects are produced by the

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* *Helmholtz.* Die Lehre von dem Tonempfindungen.

† See "Treatise on Electricity," by De la Rive, I., p. 300.

‡ Ibid.

§ *Gore.* Proceedings of Royal Society, XII., p. 217.

‖ *Page.* "Vibration of Trevelyan's bars by the galvanic current." Silliman's Journal, 1850, IX., pp. 105–108.

currents induced in the secondary wires. A rheotome was placed in circuit with the thick wires of a Ruhmkorff's coil, and the fine wires were connected with two strips of brass (A and B), insulated from one another by means of a sheet of paper. Upon placing the ear against one of the strips of brass, a sound was perceived like that described above as proceeding from an empty helix of wire during the passage of an intermittent voltaic current. A similar sound, only much more intense, was emitted by a tin-foil condenser when connected with the fine wires of the coil.

One of the strips of brass, A (mentioned above), was held closely against the ear. A loud sound came from A whenever the slip B was touched with the other hand. It is doubtful in all these cases whether the sounds proceeded from the metals or from the imperfect conductors interposed between them. Further experiments seem to favor the latter supposition. The strips of brass A and B were held one in each hand. The induced currents occasioned a muscular tremor in the fingers. Upon placing my forefinger to my ear a loud crackling noise was audible, seemingly proceeding from the finger itself. A friend who was present placed my finger to his ear, but heard nothing. I requested him to hold the strips A and B himself. He was then distinctly conscious of a noise (which I was unable to perceive) proceeding from his finger. In these cases a portion of the induced currents passed through the head of the observer when he placed his ear against his own finger; and it is possible that the sound was occasioned by a vibration of the surfaces of the ear and finger in contact.

When two persons receive a shock from a Ruhmkorff's coil by clasping hands, each taking hold of one wire of the coil with the free hand, a sound proceeds from the clasped hands. The effect is not produced when the hands are moist. When either of the two touches the body of the other a loud sound comes from the parts in contact. When the arm of one is placed against the arm of the other, the noise produced can be heard at a distance of several feet. In all these cases a slight shock is experienced so long as the contact is preserved. The introduction of a piece of paper between the parts in contact does not materially interfere with the production of the sounds, while the unpleasant effects of the shock are avoided.

When a powerful current is passed through the body, a musical note can be perceived when the ear is closely applied to the arm of the person experimented upon. The sound seems to proceed from the muscles of the fore-arm and from the biceps muscle. The musical note is the unison of the rheotome employed to interrupt the primary

circuit. I failed to obtain audible effects in this way when the pitch of the rheotome was high. Elisha Gray * has also produced audible effects by the passage of induced electricity through the human body. A musical note is occasioned by the spark of a Ruhmkorff's coil when the primary circuit is made and broken sufficiently rapidly. When two rheotomes of different pitch are caused simultaneously to open and close the primary circuit, a double tone proceeds from the spark.

9. When a voltaic battery is common to two closed circuits, the current is divided between them. If one of the circuits is rapidly opened and closed, a pulsatory action of the current is occasioned upon the other.

All the audible effects resulting from the passage of an intermittent current can also be produced, though in less degree, by means of a pulsatory current.

10. When a permanent magnet is caused to vibrate in front of the pole of an electro-magnet, an undulatory or oscillatory current of electricity is induced in the coils of the electro-magnet, and sounds proceed from the armatures of other electro-magnets placed upon the circuit. The telephonic receiver referred to above (par. 4), was connected in circuit with a single-pole electro-magnet, no battery being used. A steel tuning-fork which had been previously magnetized was caused to vibrate in front of the pole of the electro-magnet. A musical note similar in pitch to that produced by the tuning-fork proceeded from the telephonic receiver in a distant room.

11. The effect was much increased when a battery was included in the circuit. In this case, the vibration of the permanent magnet threw the battery-current into waves. A similar effect was produced by the vibration of an unmagnetized tuning-fork in front of the electro-magnet. The vibration of a soft iron armature, or of a small piece of steel spring no larger than the pole of the electro-magnet in front of which it was placed, sufficed to produce audible effects in the distant room.

12. Two single-pole electro-magnets, each having a resistance of ten ohms, were arranged upon a circuit with a battery of five carbon elements. The total resistance of the circuit, exclusive of the battery, was about twenty-five ohms. A drum-head of gold-beater's skin, seven centimetres in diameter, was placed in front of each electro-magnet, and a circular piece of clock-spring, one centimetre in diameter, was glued to the middle of each membrane. The telephones so constructed were placed in different rooms. One was retained in

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* *Elisha Gray.* Eng. Pat. Spec., No. 2646, see "Engineer," Aug. 14, 1874.

the experimental room, and the other taken to the basement of an adjoining house.

Upon singing into the telephone, the tones of the voice were reproduced by the instrument in the distant room. When two persons sang simultaneously into the instrument, two notes were emitted simultaneously by the telephone in the other house. A friend was sent into the adjoining building to note the effect produced by articulate speech. I placed the membrane of the telephone near my mouth, and uttered the sentence, "Do you understand what I say?" Presently an answer was returned through the instrument in my hand. Articulate words proceeded from the clock-spring attached to the membrane, and I heard the sentence: "Yes; I understand you perfectly."

The articulation was somewhat muffled and indistinct, although in this case it was intelligible. Familiar quotations, such as, "To be, or not to be; that is the question." "A horse, a horse, my kingdom for a horse." "What hath God wrought," &c., were generally understood after a few repetitions. The effects were not sufficiently distinct to admit of sustained conversation through the wire. Indeed, as a general rule, the articulation was unintelligible, excepting when familiar sentences were employed. Occasionally, however, a sentence would come out with such startling distinctness as to render it difficult to believe that the speaker was not close at hand. No sound was audible when the clock-spring was removed from the membrane.

The elementary sounds of the English language were uttered successively into one of the telephones and the effects noted at the other. Consonantal sounds, with the exception of L and M, were unrecognizable. Vowel-sounds in most cases were distinct. Diphthongal vowels, such as *a* (in ale), *o* (in old), *i* (in isle), *ow* (in now), *oy* (in boy), *oor* (in poor), *oor* (in door), *ere* (in here), *ere* (in there), were well marked.

Triphthongal vowels, such as *ire* (in fire), *our* (in flour), *ower* (in mower), *ayer* (in player), were also distinct. Of the elementary vowel-sounds, the most distinct were those which had the largest oral apertures. Such were *a* (in far), *aw* (in law), *a* (in man), and *e* (in men).

13. Electrical undulations can be produced directly in the voltaic current by vibrating the conducting wire in a liquid of high resistance included in the circuit.

The stem of a tuning-fork was connected with a wire leading to one of the telephones described in the preceding paragraph. While the tuning-fork was in vibration, the end of one of the prongs was dipped

into water included in the circuit. A sound proceeded from the distant telephone. When two tuning-forks of different pitch were connected together, and simultaneously caused to vibrate in the water, two musical notes (the unisons respectively of those produced by the forks) were emitted simultaneously by the telephone.

A platinum wire attached to a stretched membrane, completed a voltaic circuit by dipping into water. Upon speaking to the membrane, articulate sounds proceeded from the telephone in the distant room. The sounds produced by the telephone became louder when dilute sulphuric acid, or a saturated solution of salt, was substituted for the water. Audible effects were also produced by the vibration of plumbago in mercury, in a solution of bichromate of potash, in salt and water, in dilute sulphuric acid, and in pure water.

14. Sullivan * discovered that a current of electricity is generated by the vibration of a wire composed partly of one metal and partly of another; and it is probable that electrical undulations were caused by the vibration. The current was produced so long as the wire emitted a musical note, but stopped immediately upon the cessation of the sound.

15. Although sounds proceed from the armatures of electro-magnets under the influence of undulatory currents of electricity, I have been unable to detect any audible effects due to the electro-magnets themselves. An undulatory current was passed through the coils of an electro-magnet which was held closely against the ear. No sound was perceived until a piece of iron or steel was presented to the pole of the magnet. No sounds either were observed when the undulatory current was passed through iron, steel, retort-carbon, or plumbago. In these respects an undulatory current is curiously different from an intermittent one. (See par. 2.)

16. The telephonic effects described above are produced by three distinct varieties of currents, which I term respectively intermittent, pulsatory, and undulatory. *Intermittent currents* are characterized by the alternate presence and absence of electricity upon the circuit; *Pulsatory currents* result from sudden or instantaneous changes in the intensity of a continuous current; and *undulatory currents* are produced by gradual changes in the intensity of a current analogous to the changes in the density of air occasioned by simple pendulous vibrations. The varying intensity of an undulatory current can be

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* *Sullivan.* "Currents of Electricity produced by the vibration of Metals." Phil. Mag., 1845, p. 261; Arch. de l'Électr., X., p. 480.

represented by a sinusoidal curve, or by the resultant of several sinusoidal curves.

Intermittent, pulsatory, and undulatory currents may be of two kinds, — *voltaic*, or *induced;* and these varieties may be still further discriminated into *direct* and *reversed* currents; or those in which the electrical impulses are all positive or negative, and those in which they are alternately positive and negative.

Telephonic effects can be produced by means of currents of electricity, which are	Intermittent.	Voltaic.	Direct (See par. 1, 2, 3, 4, 5, 6).
			Reversed.
		Induced.	Direct.
			Reversed (See par. 8).
	Pulsatory.	Voltaic.	Direct (See par. 9).
			Reversed.
		Induced.	Direct.
			Reversed.
	Undulatory.	Voltaic.	Direct (See par. 11, 12, 13, 15).
			Reversed.
		Induced.	Direct.
			Reversed (See par. 10).

17. In conclusion, I would say that the different kinds of currents described above may be studied optically by means of König's manometric capsule.* The instrument, as I have employed it, consists simply of a gas-chamber closed by a membrane to which is attached a piece of clock-spring. When the spring is subjected to the attraction of an electro-magnet, through the coils of which a "telephonic" current of electricity is passed, the flame is thrown into vibration.

I find the instrument invaluable as a rheometer, for an ordinary galvanometer is of little or no use when "telephonic" currents are to be tested. For instance, the galvanometer needle is insensitive to the most powerful undulatory current when the impulses are reversed, and is only slightly deflected when they are direct. The manometric capsule, on the other hand, affords a means of testing the amplitude of the electrical undulations; that is, of deciding the difference between the maximum and minimum intensity of the current.

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* *König.* "Upon Manometric Flames," Phil. Mag., 1873, XLV., No. 297, 298.

II.

SCHEELE'S GREEN,

ITS COMPOSITION AS USUALLY PREPARED, AND SOME EXPERIMENTS UPON ARSENITE OF COPPER.

By S. P. Sharples, S.B.

Presented, June 14, 1876.

In 1778, the eminent Swedish chemist, Charles William Scheele, communicated to the Academy of Sciences at Stockholm the method of preparing the green pigment which has since borne his name. He, however, says, that it was discovered three years previously.

This pigment is of a yellowish green color, and has been long used in the arts under various names; such as, mountain green, mineral green, and Swedish green. At the time of its discovery, it was the most brilliant green obtainable.

The discovery, in 1814, of the copper aceto-arsenite, known as Schweinfurth green, Paris green, English green, and sometimes wrongly called Scheele's green, has, however, almost entirely thrown Scheele's green out of the market; and it is at the present day an unknown substance, so far as its use as a pigment is concerned; although it may be still found on the price lists of manufacturing chemists, and the receipts for its manufacture are found in works on dyeing and calico-printing. But its covering power is very low, and it is far inferior in brilliancy to its successful rival, Paris green.

Having had occasion to examine some samples of this pigment some time ago, I became convinced that the composition of Scheele's green, as laid down in the books, was altogether a matter of conjecture; since I could find no record of any analysis that had ever been made of the substance prepared according to Scheele's directions, which have been copied without change for the last hundred years.

The formula given varies with the date; Scheele himself, of course, neither made a quantitative analysis nor gave a formula. Succeeding writers seem to have followed him in the first respect, but have given formulas to correspond with their ideas of the composition that the salt should have.

The older writers give the formula $CuOAs_2O_3$, this would give the percentages of copper oxide and arsenic trioxide, as follows: —

Copper oxide,	29.50
Arsenic trioxide,	70.50
	100.00

(The atomic weights used through this paper are: oxygen, 16; copper, 63.4; the old formulas being changed to correspond to these weights. As a matter of convenience, I have made all statements of composition in terms of copper oxide and arsenic trioxide, but in so doing I have no wish to be understood as asserting that they exist as copper oxide and arsenic trioxide in the compound.)

Berzelius * gives the formula, $\dot{C}u_2\ddot{A}s$; this, in modern notation, would be $Cu_2As_2O_5$; or in percentages,

Copper oxide,	44.50
Arsenic trioxide,	55.50
	100.00

He describes the methods by which it may be obtained as either, by digesting carbonate of copper with water and arsenious acid, or by Scheele's method, giving for the latter almost exactly Scheele's receipt.

Ure † gives Scheele's receipt, and then says it consists of oxide of copper, 28.51, arsenious acid, 71.46. This corresponds to the first formula given above, $CuAs_2O_4$.

Miller ‡ gives the formula $CuHAsO_3$. This in percentages would be:

Copper oxide,	42.37
Arsenic trioxide,	52.83
Water,	4.80

This formula seems to be the favorite one at present, and may be found in most of the text-books.

Bloxam,§ in the course of his long and elaborate investigations of the arsenites, made some experiments upon copper arsenite, but failed to obtain a definite compound. The first salt made, he says, contained: —

* Ure's Dict., New York, 1847, p. 1100.
† Traité de Chémie, Tome 4, p. 182. Paris, 1847.
‡ Miller's Elements of Chemistry. London, 1864, p. 292.
§ Bloxam, C. L., Jour. Chem. Soc., 1862, p. 292.

	Per cents.	Equivalents.
Copper oxide,	40.54	1.88
Arsenic trioxide,	53.80	1.
Water,	5.67	1.16

The second contained: —

	Per cents.	Equivalents.
Copper oxide,	44.29	2.21
Arsenic trioxide,	49.98	1.00
Water,	5.73	1.26

The third product gave: —

	Per cents.	Equivalents.
Copper oxide,	46.52	2.35
Arsenic trioxide,	49.36	1.00
Water,	4.12	.92

The fourth gave: —

	Per cents.	Equivalents.
Copper oxide,	42.69	1.96
Arsenic trioxide,	52.67	1.
Water,	4.64	.97

From this last analysis he deduces the formula $\dot{C}uHAsO_3$. In a foot-note he says: "Scheele's prescription for the commercial green arsenite of copper involves 2.3 equivalents of oxide of copper for one equivalent of arsenious acid, so that Scheele's green dried at 212° F., appears to be essentially a mixture of $CuHAsO_3$, with an excess of oxide of copper."

This observation is perfectly correct if nothing is taken into the account except the quantities taken by Scheele; but Scheele himself says, in a foot-note:* "The water with which the color is lixiviated contains a little arsenic, and must not be thrown out in a place to which cattle have access." The evident tendency of this loss of arsenic would be to make the salt more basic than the formula $(CuO)_{2.32}As_2O_3$ $(H_2O)_{92}$ calls for, this being the formula which Bloxam supposes to represent Scheele's green.

In Watts's Dictionary,† under the head of arsenite of copper, this sentence occurs: "It is a light green precipitate, which dissolves in an excess of ammonia, without color, yielding a solution of arsenic acid and cuprous oxide."

Berzelius's formula is given, and the sentence just quoted is evi-

* Scheele's Essays. London, 1786, p. 254.

† Vol. I., p. 376.

dently a translation, either directly or indirectly, from the same author.

The description of copper arsenite in the French edition of Berzelius, Paris, 1847, is as follows: "The neutral salt is obtained by precipitating sulphate of copper by arsenite of potassa. The precipitate is green. When it contains an excess of base, its color is more intense; but it decomposes spontaneously, in a little time becoming a dark brown, and then contains cupric arsenate and cuprous arsenite. Caustic ammonia dissolves this salt into a colorless liquid containing, probably, cuprous arsenate." The German of 1838 is the same as the above, with the exception that it reads: "When the alkali is in excess, the color is more intense, but it decomposes in a little time," &c. "This salt" referred to in the above paragraph, is evidently the brown salt, and not the green. Moreover, the German text, and not the French, is the correct one, as is shown by my own experiments.

In this connection, the following extract is of interest. Rose says of Scheele's green: "This precipitate is soluble in an excess of ammonia, also in an excess of hydrate of potassa. The solution has in both cases a similar blue color. The blue solution formed by hydrate of potassa deposits in time reddish-brown suboxide of copper; the liquid becomes colorless, and contains arsenate of potassium. The blue solution formed by ammonia is not modified by time."

The reference from Berzelius seems to have been misunderstood by German as well as English writers, as the same statement occurs in the Handwörterbuch der Chemie, B. 2, 1858, p. 300, which says Scheele's green dissolves colorless in ammonia as arsenic acid and cuprous oxide. Graham-Otto* also repeats the same.

In the New Chemistry,† the above blunder is repeated, and two formulas are given, as follows: "Arsenite of copper, $(Cu_2O)_2As_2O_3$ or, $Cu_3(AsO_3)_2$." And the article finishes by saying there are also two hydrated salts, $CuH_4(AsO_3)_2$, and $CuHAsO_3$. The percentage composition of these salts would be as follows, supposing the above formulas are correctly given: —

	$(Cu_2O)_2As_2O_3$.	$Cu_3(AsO_3)_2$.	$CuH_4(AsO_3)_2$.	$CuHAsO_3$.
Copper oxide,	(sub. 59.06)	54.61	25.33	42.37
Arsenic trioxide,	40.94	45.39	63.18	52.83
Water,			11.49	4.80

* Vol. III., 557, 4th ed.

† Chemistry, Theoretical and Practical. Lippincott & Co.; Phila., 1876, p. 260.

In the first of these formulas, there is an evident mistake; it is a copy of the formula given by Watts, without taking into account that Watts, while doubling the atomic weight of oxygen, retained the old weight of copper, so that, corrected, this formula reads $(CuO)_2\ As_2O_3$; or, in other words, is Berzelius's formula.

But both of the formulas, one and two, are wrong, from the fact that they contain no water. No. 3 is an evident attempt to represent the acid arsenite which Berzelius mentions, and No. 4 is Blöxam's formula.

As will be seen, the whole literature of the subject is founded upon three sets of facts. Scheele's prescription, which all the authors, whom I have quoted, have given, making only such alterations as were necessary on account of changes in weights and measures. And it is a singular fact, that not one of these authors has taken the trouble to see if the quantities of copper sulphate and arsenic trioxide taken would produce a salt of the formula given; or have discovered the fact that nearly twice as much potassium carbonate is used as is necessary to saturate the sulphuric trioxide of the copper sulphate, and Scheele's foot-note has been totally ignored.

Secondly, Berzelius's account of the salt, which has evidently been misunderstood.

Thirdly, Bloxam's analyses of salts, which he would have found difficult, if not impossible, to reproduce, had he been so inclined.

After comparing the various works cited, it became a matter of interest to find out, in the first place, what Scheele's green really is, what are its properties, and whether there is more than one copper arsenite.

The experiment was tried of making copper arsenite according to the method given by Berzelius; that is, by dissolving copper carbonate in an aqueous solution of arsenic trioxide.

Hydrocopper carbonate was prepared by precipitating copper sulphate in the cold by an excess of sodium carbonate, and washing the precipitate with cold water until free from sulphates. Some of the precipitate was boiled with a saturated solution of arsenic trioxide, its blue color soon changed to a bright green, which it maintained, although boiled for upwards of an hour. The green precipitate was filtered off, and washed with hot water, until the wash waters were free from arsenic.

The substance remaining on the filter was of a bright green color, scarcely inferior to Schweinfurth green in brilliancy, although of a yellowish shade.

The green precipitate was dried and analyzed, it gave, —

ANALYSIS No. I.

	Per cents.	Atomic Ratios.
Copper oxide,	66.02	8.31
Arsenic trioxide,	8.32	.42
Carbon dioxide,	15.26	3.47
Water,	10.33	5.74
	99.93	

This corresponds well with a mixture of dibasic carbonate and tribasic arsenite.

The brown basic carbonate produced by boiling the hydrocopper carbonate with water was then boiled with arsenic trioxide, but was not changed in color. The filtrate from the green precipitate contained a large amount of arsenic, but was free from copper; and I failed to obtain on evaporation the yellowish-green acid salt spoken of by Berzelius.

Further experiments on the carbonate were tried to see if it could be completely decomposed by boiling with excess of arsenic trioxide, but they all resulted in failure.

It seems to me that Berzelius must have been misled by the production of the brilliant green arsenio-carbonate, as he gives no analysis to support his assertion.

Arsenic trioxide seems to have a very strong influence in preventing the blackening of copper carbonates and hydrates, a very small percentage preventing this well-known reaction.

A series of experiments were then tried on the production of Scheele's green, following the course laid down in the books and by Scheele himself; viz., first, the production of a more or less basic, sodium or potassium arsenite; and, secondly, the addition of this to a solution of copper sulphate.

Experiment No. 1.

		Parts.	Atomic Ratios.
Copper sulphate,	$CuSO_45H_2O$	50	2.04
Potassium carbonate,	K_2CO_3	25	1.81
Arsenic trioxide,	As_2O_3	10	.50

Dissolved the potassium carbonate in water, boiled and added the arsenic trioxide, filtered and added to the boiling solution of copper sulphate. The precipitate, when washed and dried, was of a yellowish green; the filtrate was blue.

Analysis No. II.

	Per cents.	Atomic Ratios.
Copper oxide,	56.98	7.18
Arsenic trioxide,	21.45	1.08
Sulphur trioxide,	12.80	1.60
Ferrous oxide,	1.60	.22
Water,	7.17	3.98

Experiment No. 2.

		Parts.	Atomic Ratios.
Copper sulphate,	$CuSO_4 5H_2O$	50	2.04
Potassium carbonate,	K_2CO_3	30	2.17
Arsenic trioxide,	As_2O_3	15	.76

Treated as before; filtrate pale blue, precipitate, a brighter green than No. 1.

Analysis No. III.

	Per cents.	Atomic Ratios.
Copper oxide,	49.58	6.24
Arsenic trioxide,	32.12	1.62
Sulphur trioxide,	4.42	.55
Water,	13.88	7.82

Experiment No. 3.

		Atomic Ratios.
$CuSO_4 5H_2O$,	50	2.04
K_2CO_3,	40	2.90
As_2O_3,	10	.50

Treated as before; filtrate pale yellow, precipitate had more of a yellowish tinge than before.

Analysis No. IV.

	Per cents.	Atomic Ratios.
Copper oxide,	51.26	6.43
Arsenic trioxide,	31.67	1.60
Sulphur trioxide,	5.32	.66
Water,	11.75	6.53

Experiment No. 4.

	Parts.	Atomic Ratios.
$CuSO_4 5H_2O$,	50	2.04
K_2CO_3,	50	3.61
As_2O_3,	18	.90

The potash and arsenic were dissolved and allowed to cool, then added to the cold solution of copper. The mixture effervesced strongly; half of it was allowed to stand until next day, then filtered; the other half was boiled, which operation it stood without blackening. Analysis of the first half gave, —

Analysis No. V.

	Per cents.	Atomic Ratios.
Copper oxide,	49.55	6.24
Arsenic trioxide,	38.90	1.96
Water,	11.55	6.42

The second half gave, —

Analysis No. VI.

	Per cents.	Atomic Ratios.
Copper oxide,	46.65	5.87
Arsenic trioxide,	42.94	2.17
Water,	10.41	5.78

This preparation was repeated, using the same proportions; the precipitate was boiled, and washed with hot water until the filtrate was free from arsenic.

Analysis No. VII.

	Per cents.	Atomic Ratios.
Copper oxide,	51.40	6.47
Arsenic trioxide,	39.57	1.99
Water,	8.72	4.85

This seems to indicate that either the salt is decomposed by washing with hot water, or that it consists of a strongly basic salt mixed with free arsenious acid. The first view is most likely the correct one, if we modify it so as to read: "it is decomposed by washing with either hot or cold water, forming a more basic salt."

But further experiments seem to show that this decomposition is much slower with cold than with hot water. And I have found it utterly impossible to remove the whole of the arsenic by prolonged washing.

This fact was further confirmed by an experiment of Prof. J. M. Ordway, who washed a portion of the salt with 3,000 times its weight of water, without completely decomposing it. The basic salt produced by washing does not blacken on boiling with water, thus showing that we have a true basic salt or mixtures of several basic salts, and not a mixture of Bloxam's normal arsenite, $HCuAsO_4$, and hydrate of copper.

Experiment No. 5.

In order to see if the salt $HCuAsO_4$ could be prepared by taking the exact amount of arsenic trioxide and copper sulphate necessary to form it, the following proportions were taken: —

	Parts.	Atomic Ratios.
Copper sulphate,	124.8	2.
Arsenic trioxide,	49.5	1.
Sodium carbonate,	53.	2.

The solution of arsenic in the sodium carbonate was boiled, and added, while boiling, to the solution of copper sulphate. And the ebullition was continued till all the carbonic acid was driven off. The precipitate was washed by decantation once or twice, and then divided into three portions; the first was merely drained, the second was washed a little, and the third was washed until arsenic ceased to be found in the wash-water. These portions were numbered respectively, VIII., IX., X. They all contained basic copper sulphate, and No. VIII. probably contained a little sodium sulphate.

ANALYSIS No. VIII.

	Per cents.	Atomic Ratios.
Copper oxide,	49.78	6.27
Arsenic trioxide,	35.93	1.80
Sulphur trioxide,	6.07	.76
Water,	7.56	4.20
	99.34	

ANALYSIS No. IX.

	Per cents.	Atomic Ratios.
Copper oxide,	47.71	6.00
Arsenic oxide,	43.74	2.21
Sulphur trioxide,	3.10	.39
Water,	5.47	3.04
	100.02	

ANALYSIS No. X.

	Per cents.	Atomic Ratios.
Copper oxide,	57.77	7.27
Arsenic oxide,	27.50	1.39
Sulphur trioxide,	5.27	.66
Water,	8.97	4.98
	99.51	

None of the above blackened on boiling with water, and all gave a blue solution with ammonia. Nos. VIII., IX. closely approximate a mixture of tribasic sulphate with Bloxam's salt; while No. X. is more basic than the formula for triarsenite calls for.

Experiment No. 6.

	Molecules.
Copper sulphate,	6
Sodic carbonate,	3
Arsenic trioxide,	1

The filtrate was blue and acid; the precipitate gave, —

ANALYSIS No. XI.

	Per cents.	Atomic Ratios.
Copper oxide,	60.80	7.66
Arsenic trioxide,	14.53	.73
Sulphur trioxide,	13.34	1.67
Water,	11.11	6.17

This corresponds with a mixture of tribasic arsenite and sulphate, with a little excess of copper oxide.

To the blue filtrate from the above, three molecules more of sodic carbonate were added, the filtrate was faint yellow, and free from copper, but contained arsenic; the precipitate contained a little carbonate.

ANALYSIS No. XII.

	Per cents.	Atomic Ratios.
Copper oxide,	56.71	7.14
Arsenic trioxide,	28.62	1.44
Sulphur trioxide,	1.59	.20
Water,	9.50	5.28
Carbon dioxide,	3.35	.77
	99.77	

These precipitates both dissolved in ammonia with a blue color, and stood boiling without change of color.

Experiment No. 7.

	Molecules.
Copper sulphate,	6
Potassium carbonate,	6
Arsenic trioxide,	1

Boiled for half an hour, filtrate colorless, free from copper, but contained arsenic; precipitate did not blacken on boiling, was free from carbonates, but contained basic sulphate. Washed until filtrate was free from arsenic.

ANALYSIS No. XIII.

	Per cents.	Atomic Ratios.
Copper oxide,	58.85	7.41
Arsenic trioxide,	27.08	1.37
Sulphur trioxide,	4.83	.60
Water,	8.55	4.75
	99.30	

Experiment No. 8.

Scheele's original receipt is very nearly one part by weight of arsenic to three each of copper sulphate and potassium carbonate, and is frequently so given. The proportions as given by Scheele are, eleven ounces of the first, and thirty-two of each of the others. In molecules, supposing the potassium carbonate to be pure and anhydrous, as he directs it should be, the receipt will be as follows: —

As_2O_3,	1.
CuO,	2.32
K_2CO_3,	4.34

Or nearly double the amount of potassium carbonate required in the reaction, —

$$CuSO_4 + K_2CO_3 = CuCO_3 + K_2SO_4.$$

A portion was, therefore prepared, using

	Parts.	Molecules.
Copper sulphate	6	2.35
Potassium carbonate,	3	2.17
Arsenic trioxide,	2	1.

The filtrate was slightly acid and blue, but the potassium carbonate used not quite anhydrous. The color produced was fully equal to that produced by the ordinary receipt. The filtrate contained arsenic.

ANALYSIS No. XIV.

	Per cents.	Atomic Ratios.
Copper oxide,	51.37	6.62
Arsenic trioxide,	39.94	2.02
Sulphur trioxide,	1.80	.22
Water,	6.61	3.67

This is an almost exact mixture of tribasic sulphate and arsenite. It dissolved in ammonia with a blue color, and did not blacken on boiling. The potassium carbonate may, therefore, be considerably diminished from that called for in Scheele's receipt.

Experiment No. 9.

This was nearly a repetition of Experiment No. 4 as to quantities used. The object being in this case to study more fully the effects of washing, the proportions taken approximate closely to Scheele's receipt: —

	Parts.	Molecules.
Copper sulphate,	3	2.35
Arsenic trioxide,	1	1.
Potassic carbonate,	3	4.34

The solutions were mixed and boiled for half an hour; the first (No. XV.) was washed until the wash-water was free from sulphates; the other (No. XVI.) until the wash-water was free from arsenic.

Analysis No. XV.

	Per cents.	Atomic Ratios.
Copper oxide,	52.23	6.60
Arsenic trioxide,	35.41	1.79
Sulphur trioxide,	5.88	.74
Water,	6.02	3.35
	99.54	

Analysis No. XVI.

	Per cents.	Atomic Ratios.
Copper oxide,	57.18	7.20
Arsenic trioxide,	25.62	1.30
Sulphur trioxide,	6.31	.79
Water,	10.85	3.90

Experiment No. 10.

This preparation was made exactly according to Scheele's own directions, as given by himself in the Proceedings of the Stockholm Academy, using the English translation for the weights and measures. The sample was divided after precipitation. No. XVII. was washed by decantation with the amount of water he specifies.

No. XVIII. was first boiled with water, and then washed with hot water so long as arsenic was found in the filtrate. The proportions used were, —

	Parts.
Arsenic trioxide,	11
Potassium carbonate,	32

Dissolved the potassium carbonate in thirty-two parts of water, added the arsenic trioxide boiled and filtered.

	Parts.
Copper sulphate crystallized,	32
Water,	192

Dissolved and boiled while hot; added, with constant stirring, the hot solution of arsenic trioxide.

Analysis No. XVII.

	Per cents.	Atomic Ratios. Found.	Taken.
Copper oxide,	50.76	3.10	2.32
Arsenic trioxide,	40.82	1.00	1.
Sulphur trioxide,	1.63	.10	
Water,	6.41	1.75	
	99.62		

Analysis No. XVIII.

	Per cents.	Atomic Ratios.
Copper oxide,	49.25	6.20
Arsenic trioxide,	42.66	2.15
Sulphur trioxide,	.42	.05
Water,	6.71	3.72
	99.04	

In summing up, I will first call attention to the fact that in no one of the eighteen samples does the arsenic exist in these compounds in as great a ratio as required by Bloxam's formula. Further, they all contain water, and this water is not driven off at a temperature of 150° C. In every case, arsenic was found in the filtrate, sometimes in considerable amount, as is shown by comparison of the ratios of copper sulphate and arsenic trioxide taken, and the ratios between the copper oxide and arsenic, as found in the analysis. All the samples dissolved in ammonia with a blue color.

In Experiments Nos. 4, 9, and 10 almost identical amounts of substances were taken; but the results, as will be seen, differ widely.

Scheele's green may, according to my experiments, be described as a

more or less basic copper arsenite, which may or may not contain basic copper sulphate and carbonate. The composition of it seeming to depend to a considerable extent upon the degree of concentration of the liquid from which it is precipitated. Its basicity also seems to depend to a considerable extent upon the same fact, the more dilute the solution the more basic the salt.

The composition also depends to some extent on the amount of wash-water used in washing it.

The normal pigment which is represented by Analysis XVIII. may be described as follows: —

It is of a yellowish green color, soluble in dilute acids and in caustic alkalies. It dissolves in alkalies with a blue color, and is decomposed by excess of soda or potash, or their carbonates, but is not decomposed by ammonia, even upon boiling. It does not blacken upon boiling with distilled water. When dissolved in ammonia, if a solution of soda or potash is added, the solution is [illegible] from the reduction of the copper salt to a cuprous salt.

Its average composition, as generally prepared, omitting the sulphur dioxide which is generally found in it, is about as follows: —

Copper oxide,	[illegible]
Arsenic trioxide,	[illegible]
Water,	[illegible]

This approximates closely to the formula

$$Cu_3As_2O_6, 2H_2O.$$

This formula would give the following percentages: —

Copper oxide,	[illegible]
Arsenic trioxide,	[illegible]
Water,	[illegible]

Taking this view of the subject, Scheele's green is the normal tricupric arsenite, and corresponds to the [illegible] arsenite described by Bloxam.

It is almost impossible, however, to obtain a perfectly constant product, from the strong tendency to form basic sulphates and basic arsenites.

As a matter of economy in the preparation it will be found more advantageous to take the following proportions rather than those given by Scheele: —

	Parts.
Copper sulphate,	6
Arsenic trioxide,	2
Sodium carbonate, $Na_2CO_310H_2O$,	8

Dissolve the soda and arsenic in ten parts of water, and the copper sulphate in forty parts of water; filter both solutions if necessary. Mix while boiling, boil for a few minutes, and then allow to stand until next day; pour off the supernatant liquid, fill up the vessel with hot water; repeat this operation about three times, then filter, and dry at about 100° C.

In analyzing these salts, the water was determined by ignition in a current of oxygen. The water being collected and weighed in a chloride of calcium tube. The arsenic was determined in various ways, but it was found that the conversion into arsenic pentoxide and trituration with uranium solution gave the most satisfactory results. The copper was determined with the battery.

The separation of copper and arsenic was made either by boiling with a slight excess of potassa with previous oxidation by nitric acid or bromine, or by adding potassa, and then passing hydrogen sulphide through the solution until the copper was completely precipitated.

My thanks are due to my assistant, E. R. Hills, for the able manner in which he has aided me by making many analyses of these salts, — an undertaking that can be appreciated only by those who have tried working with copper and arsenic in combination.

Since the above paper was finished, I have succeeded in obtaining two samples of copper arsenite as found in commerce. The first of these resembled closely that analyzed in Analysis No. XII. in color, and on examination it was found to contain carbon dioxide and sulphur trioxide; the other resembled Analysis No. XVIII., and, like it, contained a trace of sulphate.

BOSTON, June 1st.

III.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

I.—ON THE ETHERS OF URIC ACID.

By H. B. Hill.

(*First Paper.*)

Presented, June 14, 1876.

Although the constitution of many of the derivatives of uric acid may be said to be fairly established, the structure of uric acid itself is still a matter of conjecture. The formulæ given by Baeyer,* Kolbe,† Strecker ‡ Erlenmeyer, § Mulder, ‖ Hüfner, ¶ Gibbs, ** Medicus, †† Drechsel, ‡‡ and Mallet ; §§ differing, as they do, in points more or less essential, show that the experimental data are as yet insufficient to establish its structure. In this connection the ethers of uric acid seem to have attracted little attention. In 1864, Drygin ‖‖ prepared the diethyl and triethyl ethers by the action of ethyl iodide upon diplumbic urate. I have been unable to obtain the original paper, but from the summary of it given in the Jahresbericht ¶¶ for that year, and in Gmelin's *** hand-book, it would appear that he submitted them to no very extended examination. I have, therefore, undertaken the study of the ethers of uric acid, with the hope that a careful study of the products

* Ann. Chem. u. Pharm., 127, 235.

† Journ. für prakt. Chem. [2] 1. 184. Berichte, Deutsch. Chem. Gesellsch. III. 183.

‡ Zeitschr. für Chem. 1868, 868.

§ Zeitschr. für Chem. 1869, 176. München. Acad. Ber. 2, 276.

‖ Bericht. der Deutsch. Chem. Gesellsch. VI. 1237.

¶ Journ. für prakt. Chem. [2] 3, 23.

** Amn. Journ. [2] 46, 289.

†† Ann. Chem. u. Pharm. 175, 243.

‡‡ Chem. Centralbl. 1875, 493.

§§ Amn. Journ. Mch. 1876, 195.

‖‖ Russ. Zeitschr. Pharm. ii. 3, 28, 49, 113, 121.

¶¶ Jahresbericht. 1864, 629.

*** Gmelin, Suppl. ii. 1026.

of their decomposition may throw additional light upon the structure of uric acid.

A few preliminary experiments convinced me that the compounds in the methyl series could be much more conveniently made than those of the ethyl or benzyl. I therefore began with the methyl ethers, and this paper gives the results I have obtained in the study of the first of these.

Methyluric acid, $C_5H_3(CH_3)N_4O_3$.

Methyluric acid may readily be prepared by the action of methyl iodide upon monoplumbic urate. The metathesis takes place slowly at 110°–130°, rapidly between 160° and 165°. The dry lead salt mixed with methyl iodide in molecular proportions, enough ether being added to keep the mixture fluid, is heated in sealed tubes for eighteen hours at 165°. After the evaporation of the ether, the product of the reaction is boiled with water, and the solution filtered from the unaltered plumbic urate. The lead is then precipitated with hydric sulphide, and the plumbic sulphide filtered off boiling hot. The filtrate deposits, on cooling, methyluric acid in small crystals. These are dissolved in dilute potassic hydrate, the solution boiled for a few minutes, reprecipitated by hydrochloric acid, and recrystallized from boiling water. The yield is about 60% of the amount theoretically required by the lead salt which enters into the reaction. 220 grms. plumbic urate gave 54 grms. methyluric acid, and 89 grms. of unaltered lead salt. Afterwards, in working up the recovered lead salt, which was much more compact in form than the salt originally employed, I found the decomposition almost complete. In this case 100 grms. lead salt gave me 41 grms. methyluric acid. A portion of the uric acid is completely decomposed, and is found as ammonium salt in the mother liquors and the crude product. I attempted to increase the yield by employing anhydrous ether in the place of common ether. Although no ammonium compounds were then formed, a much smaller percentage of the lead salt entered into reaction. Longer heating at a lower temperature did not increase the yield, inasmuch as a larger quantity of dimethyl ether was then formed. The amount of dimethyl ether formed by heating to 165° is small; and as it is much more soluble in water than the monomethyl ether, it may readily be removed by recrystallization.

Methyluric acid crystallizes in small clear flat prisms, apparently of the trimetric system, the crystals being often pointed at either end. By slow cooling of a dilute solution, these crystals sometimes reach a

length of 2–3 mm., but they are usually much smaller. The substance undergoes no visible change when heated to about 300° ; at a higher temperature, it melts with complete decomposition, and without perceptible sublimation. It is soluble in boiling water, almost insoluble in cold water or in boiling alcohol; insoluble in ether. Cold concentrated sulphuric acid dissolves it abundantly; upon dilution it crystallizes out, apparently unchanged. Air-dried it contains water, a portion of which it loses at 100° ; the rest slowly, but completely, at 160°.

1.3887 grm. substance air-dried lost at 165° 0.1124 grm. = 8.09 %.

The formula $C_5H_3(CH_3)N_4O_3 . H_2O$ requires 9.00 %. Of substance dried at 100° : —

1. 0.7772 grm. lost at 165° 0.0399 grm. = 5.13 %.
2. 0.4953 „ „ 0.0289 „ = 5.83 %.
3. 0.4670 „ „ 0.0238 „ = 5.10 %.
4. 0.8106 „ „ 0.0451 „ = 5.57 %.

The formula $C_5H_3(CH_3)N_4O_3 . \frac{1}{2}H_2O$ requires 4.77 %.

From these determinations, it would appear that water is not a definite constituent of the compound. The microscopic appearance of the substance remains unchanged.

The substance dried at 165° has the formula $C_5H_3(CH_3)N_4O_3$, as the following analyses show: —

1. 0.4284 grm. gave 0.1310 grm. H_2O, and 0.6210 grm. CO_2.
2. 0.2748 grm. gave 0.0985 grm. H_2O, and 0.3972 grm. CO_2.
3. 0.1822 grm. gave 50.0 cc. nitrogen, at 20°.5, and 754.3 mm. pressure.

	Calculated for $C_6H_6N_4O_3$.	Found. 1	2	3
C	39.56	39.53	39.43	
H	3.30	3.39	3.98	
N	30.77			30.98

To determine the solubility in boiling water, a boiling saturated solution was filtered through a hot water filter into tared flasks. After cooling, the flasks were weighed, the contents washed out, evaporated in platinum, and the residue dried at 165°.

1. 52.290 grm. solution left 0.2043 grm. residue.
2. 55.379 grm. solution left 0.2187 grm. residue.

The boiling saturated solution contains, therefore, the percentages, —

1	2
0.3906	0.3950

A boiling solution was allowed to stand overnight at a temperature of about 20°. For three hours before filtering, it was kept at 20°, with constant stirring. Portions of the filtered solution were weighed, evaporated, and the residue dried at 165°,—

1. 39.020 grm. solution gave 0.0083 grm. residue.
2. 49.854 grm. solution gave 0.0111 grm. residue.

The solution saturated at 20° contained, therefore, in percentages,—

1	2
0.0213	0.0223

As the mean of these determinations, we find that there is required for the solution of one part of methyluric acid 253.6 parts of boiling water, and 4596 parts of water at 20°.

The aqueous solution reddens litmus feebly, and decomposes carbonates readily on heating. A solution in potassic or sodic hydrate is not precipitated by carbonic dioxide. From a concentrated cold solution, stronger acids precipitate it gelatinous, from hot or dilute solutions crystalline.

With bases methyluric acid forms a series of definite salts, some of which have been studied by Mr. O. R. Jackson in this laboratory. The results of this investigation he presents to the Academy in a separate communication. He has shown that the monomethyl ether of uric acid is itself a dibasic acid, like uric acid; a fact which is certainly remarkable, and of obvious theoretical importance.

Action of Hydrochloric Acid.

In 1867, Strecker * showed that uric acid heated with fuming hydrochloric or hydriodic acid to 170° assimilates five molecules of water, giving carbonic dioxide, ammonia, and glycocoll,—

$$C_5H_4N_4O_3 + 5H_2O = 3CO_2 + 3NH_3 + C_2H_5NO_2.$$

The inferences which he drew † from this reaction concerning the structure of uric acid are well known. Emmerling ‡ has recently shown that cyanogen gas passed into boiling hydriodic acid is converted into glycocoll, and seeks thus to give Strecker's reaction a new interpretation. In either case, however, it seemed to me of importance to

* Ann. Chem. u. Pharm. 146, 142; Zeitschr. für Chem. 1868, 215.
† Zeitschr. für Chem. 1868, 863.
‡ Berichte Deutsch. Chem. Gesellsch. VI. 1351.

determine the products of the decomposition of methyluric acid under these conditions.

Two tubes, each containing 1.3 grm. methyluric acid, and an excess of hydrochloric acid saturated at 0°, were heated four or five hours at 170°. The gas which escaped on opening the tubes was found to contain no methyl chloride. The excess of acid was driven off on the water bath, and the residue distilled with plumbic hydrate until the distillate was no longer alkaline. The ammoniacal distillate was caught in hydrochloric acid, and evaporated to dryness on the water bath. The residue was treated with a small quantity of absolute alcohol, and the filtered solution again evaporated to dryness. There was then left a white saline residue, which gave with great readiness Hofmann's isocyanide reaction, showing the presence of a monamine. The chloride was converted into the platinum salt, and this was analyzed after recrystallization from hot water.

0.4760 grm. gave on ignition 0.1991 grm. platinum.

	Calculated for $(CH_3NH_3)_2PtCl_6$	Found.
Pt	41.61	41.82

Methylamine is, therefore, one of the products of the reaction.

From the residue left on distillation, it was easy to isolate glycocoll in the ordinary way. The liquid was filtered from the basic plumbic chloride, the lead removed from the solution by hydric sulphide, and the filtrated evaporated. On standing, glycocoll crystallized out with its characteristic properties. For its identification, it was converted into the copper salt by boiling with freshly precipitated cupric oxide, and precipitation of the blue solution by alcohol. Of this salt, —

0.4400 grm. lost at 130° 0.0388 grm.

	Calculated for $(C_2H_4NO_2)_2Cu \cdot H_2O$	Found.
H_2O	7.85	7.68

A determination of copper in the dry salt gave, —

0.4068 grm. left on ignition 0.1523 grm. CuO.

	Calculated for $(C_2H_4NO_2)_2Cu$	Found.
CuO	37.55	37.43

The reaction in this case may therefore be writtten, —

$$C_5H_3(CH_3)N_4O_3 + 5H_2O = 3CO_2 + 2NH_3 + CH_3NH_2 + C_2H_5NO_2.$$

It will be seen that this reaction proves the commonly accepted view that uric acid is not an hydroxyl but an imid acid.

In order further to establish the relative position of the methyl radical, it seemed to me of chief importance to follow it through oxidation in alkaline and acid solution, and thus determine its relation to allantoin and alloxan or paraban.

Methylallantoin. $C_4H_5(CH_3)N_4O_3$.

Methyluric acid is readily oxidized in alkaline solution, according to the method of Claus and Emde.* The solution must be dilute with but a small excess of alkali, the potassic permanganate added slowly in exact molecular proportion. As soon as the manganese dioxide has separated, it must be filtered rapidly with the aid of the pump, and the filtrate slightly acidified with acetic acid. I then found it most advantageous to evaporate as quickly as possible on the water bath to small volume. After standing twenty-four hours, the methylallantoin crystallizes out in clusters of radiated prisms. These separated from the mother liquor by pressure, and recrystallized several times from hot water, form clear distinct monoclinic prisms, closely resembling ordinary allantoin. They are readily soluble in hot water, sparingly in cold; almost insoluble in alcohol, hot or cold, and insoluble in ether. These crystals melt with decomposition at 225°.

In spite of many variations of the method, I could obtain in this way but fifteen per cent of the theoretical yield. From the mother liquors evaporated to a syrup, alcohol separates a potash salt, probably of methylallantoic acid. On account of its uninviting character it was not further examined.

Methylallantoin dried at 100° gave, on analysis, —

0.2362 grm. gave 0.1092 grm. H_2O, and 0.2978 grm. CO_2.

	Calculated for $C_4H_5(CH_3)N_4O_3$.	Found.
C	34.89	34.39
H	4.65	5.13

Silver nitrate gives in a hot saturated solution on the cautious addition of ammonic hydrate, a crystalline precipitate consisting of needles or short prisms. This salt is readily soluble in hot water, more sparingly in cold. By spontaneous evaporation of the cold solution,

* Berichte Deutsch. Chem. Gesellsch. VII. 226.

tolerably perfect crystals of the trimetric system were obtained. This compound may be dried, without decomposition, at 100°, and gave then on analysis, —

0.1668 grm. left on ignition 0.0646 grm. silver.

	Calculated for $AgC_4H_4(CH_3)N_4O_3$.	Found.
Ag	38.71	38.61

Baeyer * has shown that allantoin, when heated with hydriodic acid, breaks up into urea and hydantoin; and it was evident that methyl-allantoin should give an analogous reaction. I therefore heated methylallantoin with concentrated hydriodic acid, following the directions given by Baeyer.† When the reaction appeared to be ended, the liberated iodine was reduced with sulphide of hydrogen, and the hydriodic acid removed by plumbic carbonate. The filtrate gave on evaporation, after standing for some time, clear crystals, which, freed from the syrupy mother liquor, and recrystallized from water, formed transparent prisms, readily soluble in water or alcohol, and giving no precipitate with zincic chloride. Their melting point I found to be 144°–145°. The quantity at my disposal was insufficient for analysis, but there can be no doubt of the identity of this substance with methyl hydantoin described by Neubauer ‡ as resulting from the action of baric hydrate upon creatinine, inasmuch as he gives these properties and the melting point 145°. The reaction may, therefore, be written, —

$$C_4H_5(CH_3)N_4O_3 + H_2 = CO\begin{array}{l} / NH_2 \\ \backslash NH_2 \end{array} + CO\begin{array}{l} / N(CH_3)-CH_2 \\ \backslash NH-CO \end{array}$$

Once, as the action of the hydriodic acid was longer continued, I obtained a substance crystallizing in broad rhombic plates, readily soluble in water, sparingly soluble in alcohol, which gave a precipitate with an alcoholic solution of zincic chloride. These crystals melted at 105°, and sublimed readily at 100°. They were evidently sarcosine formed from the decomposition of methylhydantoin.

* Ann. Chem. u. Pharm. 117, 178.
† Ann. Chem. u. Pharm. 130, 158.
‡ Ann. Chem. u. Pharm. 137, 288.

Oxidation of methyluric acid with nitric acid.

By the oxidation of methyluric acid with nitric acid, a solution is obtained which gives a deep red coloration on warming with ammonic hydrate. From this solution, however, I have as yet been unable to isolate a crystalline product. By spontaneous evaporation in the air, a sticky syrup is obtained, which does not solidify, even after long standing *in vacuo* over sulphuric acid. Alcohol dissolves this residue, the solution remains clear after the addition of ether, and on evaporation again leaves an uncrystallizable syrup. I have been equally unsuccessful in separating by stannous chloride or sulphide of hydrogen a crystalline alloxantine or dialuric acid. Oxidation with potassic chlorate and hydrochloric acid, according to the method of Schlieper,* gave the same result. These reactions were sufficient to give a qualitative proof that the solution did not contain ordinary alloxan. I therefore attempted to prepare from this solution a methylalloxanate in form fit for analysis. I first tried with baric hydrate to form the barium salt. The ordinary method, following closely the directions of Schlieper,† gave me, however, a salt containing but a trace of nitrogen and with percentages of barium, carbon, and hydrogen, closely approximating those required by a basic baric mesoxalate, $BaC_3O_5.BaO_2H_2$. At the same time a strong smell of methylamine was perceived. If a smaller quantity of baric hydrate were added in the cold, and then alcohol in excess, a barium salt was thrown down which contained nitrogen, but it could not in this way be obtained of constant composition. Plumbic hydrate seemed to determine the formation of the methylalloxanate, but no better results were obtained. The silver salt blackened too rapidly to admit of analysis.

The lime salt is the only one I have been able to prepare with constant composition. Methyluric acid is dissolved in as small a quantity of nitric acid of 1.42 sp. gr. as possible. the solution somewhat diluted, and the excess of acid neutralized with calcic carbonate in the cold. The solution is then allowed to stand *in vacuo* for some time, to free it from carbonic dioxide, afterwards diluted with six or eight volumes of alcohol and filtered. The cautious addition of ammonic hydrate to the filtrate throws down a bulky semigelatinous precipitate, which, well washed with alcohol, and dried at 100°, forms an amorphous powder, which has a faint pink color, — undoubtedly caused by a trace of alloxan. The dry salt was soluble in cold water, though with some difficulty.

* Ann. Chem. u. Pharm. 55, 261.
† Ann. Chem. u. Pharm. 55, 272.

Analysis gave for substance dried at 100°, —

1. 0.1778 grm. gave 0.1125 grm. $CaSO_4$.
2. 0.2275 grm. gave 0.1446 grm. $CaSO_4$.
3. 0.3049 grm. gave 36.8 cc. nitrogen at 21°.5, and 762.1 mm. pressure.

	Calculated for	Found.		
	$C_4H(CH_3)N_2O_5Ca$	1	2	3
Ca	18.87	18.61	18.69	
N	13.21			13.68

The analyses 1 and 2 were made with different preparations.

If ammonic hydrate be first added, and the calcic salt then precipitated by alcohol, the salt contains too little nitrogen A sample prepared in this way gave, on analysis, 20.88 % Ca, and 10.75 % N. So also if the precipitate thrown down by ammonic hydrate in alcoholic solution be dissolved in water, and reprecipitated by alcohol, the percentage of calcium is increased, and the nitrogen diminished. Analysis gave 20.49 % Ca.

Inasmuch as the chief point was to prove the formation of methylalloxan by this oxidation, I distilled the calcium salt, prepared in the manner described, with potassic hydrate in a current of steam. The ammoniacal distillate readily gave the characteristic isocyanide reaction by heating with alcoholic potash and chloroform. It was neutralized with hydrochloric acid, evaporated, and from the residue the methylamine chloride separated by absolute alcohol. An analysis of the platinum salt gave —

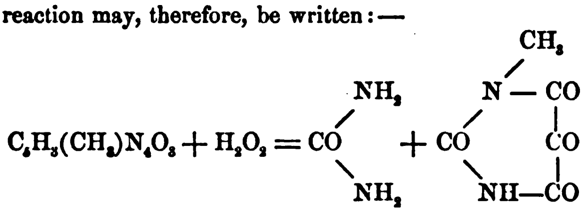
0.2160 grm. left on ignition 0.0902 grm. platinum.

	Calculated for	Found.
	$(CH_3NH_3)_2PtCl_6$	
Pt	41.61	41.76.

Thus proving that the calcium salt contained the group $= N - CH_3$.

In further confirmation, I was able to isolate common urea as the secondary product of the methylalloxan formation. After oxidizing with hydrochloric acid and potassic chlorate, the excess of acid was driven off by evaporation at gentle heat, the potassic chloride separated with absolute alcohol, and the alcoholic solution evaporated to a syrup. The cautious addition of strong nitric acid caused the separation of abundant crystals of urea nitrate in characteristic form. The base, set free as usual with baric carbonate, after recrystallization from water, melted at 129°–130°.

The reaction may, therefore, be written: —



Methylparaban, $C_3H(CH_3)N_2O_3$.

Although methylalloxan is so unstable in the presence of bases, in acid solution it possesses remarkable stability. It may be boiled for some time with strong nitric acid, or with hydrochloric acid and potassic chlorate before the red coloration with ammonia disappears. On prolonged boiling (about an hour) with strong nitric acid, the oxidation is complete, and the solution contains methylparaban. For its preparation I have found it most advantageous to boil methyluric acid with five or six parts of nitric acid of sp. gr. 1.3, until a drop taken out gives no coloration with ammonia. The excess of acid is then driven off on the water bath, the syrupy residue diluted with a little water, and well shaken out with ether. On distilling off the ether, a syrup remains which soon crystallizes in shining radiated prisms, which are recrystallized from hot water. They are somewhat difficultly soluble in cold water, readily in hot; soluble in alcohol and ether. The substance melts at 149°.5, sublimes very slowly at 100°, and at higher temperature with great readiness. For analysis, the air-dried substance was heated three hours at 100°; during that time 0.2260 grm. lost 0.0030 grm.

1. 0.1714 grm. gave 0.2333 grm. CO_2.*
2. 0.2160 grm. gave 0.0785 grm. H_2O, and 0.2629 grm. CO_2.

	Calculated for	Found.	
	$C_4N_2H_4O_3$	1	2
C	37.50	37.12	37.48
H	3.13		4.04

The substance gives no precipitate with calcic chloride, even after the addition of ammonic hydrate. On warming the ammoniacal solution, a precipitate falls not wholly soluble in acetic acid. Argentic nitrate precipitates it only in concentrated solution. The silver salt prepared from concentrated solution, with the cautious addition of

* The hydrogen in this analysis was lost.

ammonic hydrate, crystallizes in prismatic needles; quite readily soluble in hot water, sparingly in cold. Under the microscope it crystallizes from hot aqueous solution in rhombic plates. It may be dried at 100° without decomposition. It gave on analysis, —

0.1210 grm. left on ignition 0.0556 grm. silver.

	Calculated for $AgC_4N_2H_5O_3$.	Found.
Ag	45.95	45.95

There can be no doubt that this substance is identical with that obtained by Dessaignes * from creatinine, which was first recognized by Strecker † as methylparaban. Dessaignes gives no melting point, but the description given corresponds perfectly with the substance I have obtained; the only difference being that I find the substance quite readily soluble in ether, whereas he gives it as somewhat soluble only.

A consideration of the bearing of these facts upon the structure of uric acid I shall postpone until I have obtained further results.

II. — ON SOME OF THE SALTS OF METHYLURIC ACID, $C_5H_3(CH_3)N_4O_3$.

By Oscar R. Jackson.

Presented, June 14, 1876.

This work was undertaken with the purpose of proving the basicity of methyluric acid. The acid was obtained by the method described by Prof. H. B. Hill, under whose direction the preparation and analyses of the salts were conducted.

Owing to the fact that all the dibasic salts absorb carbonic acid very readily when exposed to air, as is the case with the salts of uric acid, special means had to be taken to dry the salts in an atmosphere free from carbonic acid. For this purpose they were dried *in vacuo* over sulphuric acid, and a few pieces of potassic hydrate were also placed under the receiver when the dibasic salts were dried. For the determination of the water of crystallization, the salts were heated to

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* Ann. Chem. u. Pharm. 97, 343.
† Ann. Chem. u. Pharm. 118, 164.

140° to 150° in a current of air; the air being first caused to pass through a series of six tubes, each $2\frac{1}{2}$ feet long; two being filled with solid potassic hydrate, and the remaining four with calcic chloride. The substance being weighed before and after heating, the water was estimated by the loss of weight. The bases were then estimated in the anhydrous salts by the methods given below.

Dipotassic methylurate, $K_2C_5H(CH_3)N_4O_3 . 3H_2O$.

This salt was made by suspending about one gramme of the acid in ten or fifteen cubic centimetres of boiling water in a small flask, and then adding a solution of potassic hydrate in large excess over the amount necessary to dissolve the acid. The solution was then boiled for some time, and about 100 cc. of alcohol added. On the addition of the alcohol, the salt separates out in a flocculent form. The flask is then corked up, to avoid exposure to carbonic acid, and allowed to stand twenty-four hours. The precipitate is then filtered off rapidly by the Bunsen pump, washed with alcohol, and dried *in vacuo* over sulphuric acid and potassic hydrate.

This salt when dry is an amorphous flocculent substance, and is very soluble in hot water; but when a hot solution cools, the salt does not separate out, but becomes a gelatinous mass resembling glue. This salt absorbs carbonic acid very readily from the air. When carbonic acid is passed through a solution of this salt, the monopotassic salt is probably formed, though no precipitate falls.

The water of crystallization was determined by the method given above. For the determination of the potassium, the anhydrous salt was ignited in a platinum crucible; and, after the residue had been burned as white as possible, it was treated with a few drops of hydrochloric acid. The excess of hydrochloric acid was then driven off, and the crucible ignited gently to avoid decrepitation, and then finally heated to dull redness for a few seconds.

0.3700 grm. of salt dried *in vacuo* gave 0.0635 grm. H_2O	= 17.17 %
Calculated for $K_2C_5H(CH_3)N_4O_3 . 3H_2O$	= 17.29 %
0.4974 grm. of dried salt gave 0.2367 grm. KCl; K	= 24.95 %
Calculated for $K_2C_5H(CH_3)N_4O_3$	= 25.04 %

Monopotassic methylurate, $KC_5H_2(CH_3)N_4O_3 . H_2O$.

This salt was made by suspending about one gramme of the acid in ten or fifteen centimetres of boiling water, and adding potassic carbon-

ate in slight excess over the calculated amount. The acid dissolves on the addition of the potassic carbonate with disengagement of carbonic acid. The solution was then boiled for some time, until the effervescence ceased, and precipitated with alcohol; allowed to stand twenty-four hours, filtered, washed with alcohol, and dried as in the case of the dipotassic salt.

This salt is quite like the dipotassic salt. It is very soluble in hot water, gelatinous on cooling, and is insoluble in alcohol.

The method of analysis was the same as for the dipotassic salt, with the exception that the potassium was estimated in the hydrous salt.

0.3161 grm. of salt dried *in vacuo* gave 0.0228 grm. H_2O = 7.21 %
Calculated for $KC_5H_2(CH_3)N_4O_3 . H_2O$ = 7.56 %

0.3766 grm. of salt dried *in vacuo* gave 0.1152 grm. KCl; K = 16.01 %
Calculated for $KC_5H_2(CH_3)N_4O_3 . H_2O$ = 16.42 %

Disodic methylurate, $Na_2C_5H(CH_3)N_4O_3 . 3H_2O$.

This salt was made by dissolving the acid in an excess of sodic hydrate and precipitating with alcohol, exactly as in the case of the dipotassic salt, which it closely resembles.

The analysis was conducted in the same way as above.

0.6691 grm. of salt dried *in vacuo* gave 0.1287 grm. H_2O = 19.23 %
Calculated for $Na_2C_5H(CH_3)N_4O_3 . 3H_2O$ = 19.28 %

0.4548 grm. dried salt gave 0.2304 grm. NaCl; Na = 19.92 %
Calculated for $Na_2C_5H(CH_3)N_4O_3$ = 20.35 %

Monosodic methylurate, $NaC_5H_2(CH_3)N_4O_3 . H_2O$.

This salt was made by adding, very carefully, a solution of Na_2SO_4 to a boiling-hot solution of monobaric methylurate until there is no further precipitate of baric sulphate. The solution was then filtered from the $BaSO_4$, evaporated to a very small quantity, and then precipitated with a large amount of alcohol 100 to 150 cc.; allowed to stand twenty-four hours, filtered, washed with alcohol, and dried *in vacuo*. This salt does not seem to be quite as gelatinous as the rest, and is much more soluble in dilute alcohol.

In the analysis of this salt the water was determined as above, and the sodium by ignition of the anhydrous salt, and treated with a few drops of sulphuric acid.

0.1944 grm. of salt dried *in vacuo* gave 0.0150 grm. H_2O = 7.81 %
Calculated for $NaC_5H_2(CH_3)N_4O_3 . H_2O$ = 8.10 %

0.1799 grm. of dried salt gave 0.0613 grm. Na_2SO_4; Na = 11.00 %
Calculated for $NaC_5H_2(CH_3)N_4O_3$ = 11.27 %

Dibaric methylurate, $BaC_5H(CH_3)N_4O_3 . 3\frac{1}{2}H_2O$.

This salt was made by dissolving one gr. of the acid in as little boiling water as possible in a small flask, and adding twenty-five cc. of cold saturated solution of baric hydrate. The solution was then boiled for some time, corked up, and allowed to stand. The salt separates out in very minute needles, clustered together in places, and of a slightly greenish tinge. The salt was collected on a filter, and washed rapidly with a very small quantity of cold water, and then dried *in vacuo*. The chief feature of this salt is, that it is the only one of the salts obtained which shows the slightest tendency to assume a crystalline form. It is also the most insoluble of any of the salts.

The salt prepared in this way gave, in several analyses, too great a percentage of barium. It was found impossible to free it from the excess of baric hydrate by washing on account of the ready solubility of the salt.

The water was determined as before, and the barium by ignition of the anhydrous salt in a platinum crucible, and treatment with a little sulphuric acid. The excess of acid was driven off, and then the crucible heated for some time in a current of air to oxidize any sulphide which might have been formed.

1.2318 grm. salt dried *in vacuo* gave 0.1979 grm. H_2O = 16.06 %
Calculated for $BaC_5H(CH_3)N_4O_3 . 3\frac{1}{2}H_2O$ = 16.57 %

0.4738 grm. dried salt gave 0.3656 grm. $BaSO_4$; Ba = 44.07 %
Calculated for $BaC_5H(CH_3)N_4O_3$ = 43.22 %

Monobaric methylurate, $BaC_5(H(CH_3)N_4O_3)_2 . 4H_2O$.

For the preparation of this salt, about one gramme of the acid was suspended in boiling water, and baric carbonate added until no more would dissolve. The solution was then boiled for some time, and filtered from the undissolved baric carbonate, and precipitated by alcohol. On the addition of alcohol, it separates out as white powder. It is very soluble in hot water, and solidifies on cooling into a white jelly-like mass.

The analysis was made as in the case of the dibarium salt.

0.5073 grm. salt dried *in vacuo* gave 0.0614 grm. H_2O	= 12.10 %
Calculated for Ba $(C_5H(CH_3)N_4O_3) . 4H_2O$	= 12.60 %
0.4472 grm. dried salt gave 0.2109 grm. $BaSO_4$; Ba	= 27.73 %
Calculated for $Ba(C_5H(CH_3)N_4O_3)_2$	= 27.45 %

Monocalcic methylurate, $Ca(C_5H(CH_3)N_4O_3)_2 . 3H_2O$.

This salt was made from calcic carbonate in the same manner as the monobarium salt, except that it was found necessary to boil the acid with the carbonate for several hours, in order to ensure the complete conversion of the acid.

This salt has nearly the same properties as the monobarium salt. It is a grayish substance, very soluble in hot water, and gelatinizes on cooling.

The analysis was conducted as in the case of the barium salts.

0.2123 grm. salt dried *in vacuo* gave 0.0244 grm. H_2O	= 11.49 %
Calculated for $Ca(C_5H(CH_3)N_4O_3)_2 . 4H_2O$	= 11.89 %
0.1864 grm. of dried salt gave 0.0600 grm. $CaSO_4$; Ca	= 9.43 %
Calculated for $Ca(C_5H(CH_3)N_4O_3)_2$	= 9.95 %

A dicalcium salt has been obtained by the action of methyluric acid on calcic hydrate, but has not yet been analyzed.

The action of methyluric acid on plumbic carbonate was tried with expectation of obtaining a lead salt, but the reaction does not seem to work easily, for though carbonic acid is evolved, and sulphide of hydrogen gives a slight precipitate with the filtrate, still the salt which separates out on cooling does not seem to be homogeneous, and on analysis gives but a very small percentage of lead. It probably consists of the free acid with a small amount of lead salt.

We thus see that there are two distinct sets of salts, and it is evident that methyluric acid is dibasic, — a fact of considerable theoretical interest, inasmuch as uric acid only forms two sets of salts, and not without some bearing on the constitution of uric acid.

Before closing, I wish to express my sincere thanks to Prof. H. B. Hill for his valuable advice, and for the kind interest which he has taken in the progress of this work.

IV.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XI. ON THE EFFECT OF TEMPERATURE ON THE VISCOSITY OF AIR.

BY SILAS W. HOLMAN.

Read, June 14, 1876.

THE developments of the "kinetic theory" of gases made within the last ten years have enabled it to account satisfactorily for many of the laws of gases. The mathematical deductions of Clausius, Maxwell and others, based upon the hypothesis of a gas composed of molecules acting upon each other at impact like perfectly elastic spheres, have furnished expressions for the laws of its elasticity, viscosity, conductivity for heat, diffusive power and other properties. For some of these laws we have experimental data of value in testing the validity of these deductions and assumptions. Next to the elasticity, perhaps the phenomena of the viscosity of gases are best adapted to investigation.

According to the kinetic theory, the molecules of the gas are constantly in rectilinear motion. In virtue of their mass and velocity, these molecules have a certain momentum. Hence, if we have two layers of air moving over each other, we shall have a mutual interchange of momentum from the transference of molecules from one layer to another, the result being a tendency toward an equalization of the velocities of the two layers. This produces the effect of friction between the two layers, and its amount determines the viscosity of the gas in any particular case. From analytical considerations Maxwell has deduced* an expression which, as corrected by Clausius,† should read,

$$\eta = \frac{Mu}{4\pi s^2}$$

where η is the coefficient of viscosity of any gas; M is the mass of a molecule; u the "velocity of mean square" of the molecules; and s the dis-

* Phil. Mag. xix., xx.; 1860. † Phil. Mag. xix., 434.

tance between the centres of two molecules at impact. The value of η is expressed in units of length, mass and time, since it is a tangential force. This formula, if true, shows that the viscosity of any gas should be independent of its density at a constant temperature, and should increase proportionally to the value of u. But u^2 is proportional to the absolute temperature, whence we see that the viscosity should increase proportionally to the square root of the absolute temperature (which we may reckon from $-273°$C.). Maxwell has also pointed out * that in this expression we should obtain the same result with regard to the pressure, whatever assumption we adopt of the mutual action at impact of the molecule; but that it is necessary to make some special assumption upon the nature of this action to determine the variation with the temperature.

Previous to this deduction by Maxwell, there had been but little work done upon the viscosity of gases, and almost nothing as to its variation with temperature. Subsequently, experiments have been made by Meyer, Maxwell, Puluj, and von Obermayer. The forms of apparatus used have depended upon two fundamental methods: 1°, the retardation of pendulums by the surrounding gases; 2°, the transpiration of gases through capillary tubes. In the present paper, I propose to discuss somewhat the value of these experiments in determining the variation of the viscosity with the temperature, and to describe some recent experiments made with a modification of the second of the above methods.

In a paper published in Poggendorff's Annalen, cxxv., 177, 1865, O. E. Meyer describes a series of experiments upon the internal friction of air made by measuring the retardation of three circular glass plates oscillating around a vertical axis in a closed receiver containing the gas, whose temperature and pressure could be varied. From the results of these measurements, Meyer concludes that the coefficient of viscosity is independent of the pressure. It will, however, be evident, upon an inspection of the published results, — especially by application of the graphical method, — that no reliance can be placed upon them for determining variation with the temperature. Meyer's second paper (Pogg. Ann. cxxvii., 199, 353) is devoted to a discussion of Graham's transpiration experiments,† from which we may derive quite a satisfactory proof of the law of Poiseuille as applied to gases. In the Philosophical Transactions, London, 1866, Maxwell published a series

* Phil. Mag. xxxv., 211.
† Phil. Trans. Roy. Soc. Lond. 1846–49.

of results obtained by a similar apparatus to that used by Meyer. From these Maxwell concludes that the viscosity is independent of the pressure upon the gas, and that it increases as the first power of the absolute temperature. If, however, the results published in that paper be all upon which this law is based, we cannot regard it as very securely established. A third paper was published by Meyer, in Pogg. Ann. cxliii., 14; in which the results of seven experiments with oscillating plates after Maxwell's pattern, but with bifilar suspension, were given. These, like the others, are insufficient to determine the effect of temperature. In three subsequent papers* by Meyer a large number of experiments are described. These were made by the method of transpiration through capillary tubes, and preliminary experiments were made to prove the validity of the law of Poiseuille. This law may be expressed by the following equation: —

$$V = \frac{\pi R^4 t}{8 \eta \lambda} \cdot \frac{p_1^2 - p_2^2}{2p} \qquad (1.)$$

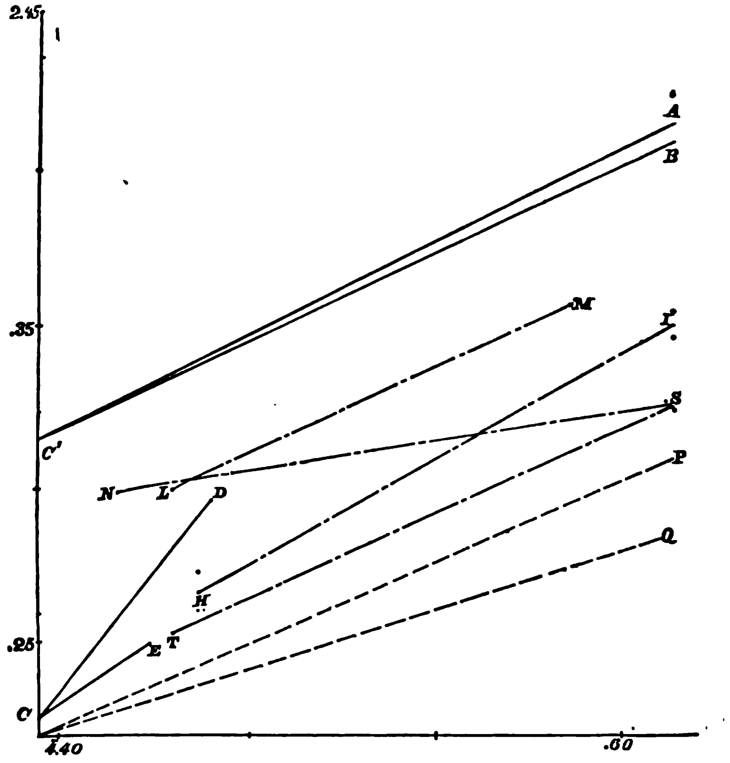
where V is the volume of gas transpired in the time t, measured at the temperature of the capillary, and under the pressure p; the pressure at entering the tube being p_1, and at leaving it p_2. The length of the capillary is λ, and its radius R; η being the coefficient of viscosity of the gas. This law may, I think, be regarded as established for variations of pressure not exceeding two atmospheres, and for tubes in which the length is very large as compared with the diameter.

Meyer gives a series of twenty-five experiments, and selects eleven as the most reliable. These all seem to indicate an increase of viscosity with rising temperature greater than the ½ power, but appear at the same time quite discordant among themselves. Upon the accompanying figure, I have shown the extremes of these by a graphical representation. The method used to discuss them is one described in the Proceedings of the Academy for 1874, page 222. If we have a line of the general form represented by the equation $y = mx^n$, we may take logarithms of both sides and get the equation, $\log y = n \log x + \log m$, which has the form of the equation to a straight line. Hence, if we have the coördinates of a series of points which we suppose may be connected by a curve of the exponential form, we may determine this fact by plotting logarithms of these coördinates, which should give us points along a straight line whose tangent is the exponent in the primary equation. Thus, if our equation to the variation of η with the

* Pogg. Ann. cxlviii., 1, 203, 526.

absolute temperature τ be of the supposed form $\eta = c\tau^x$, where c is a constant, we may take the value of log η and log τ from our experiments, and expect upon plotting them to get a straight line making an angle whose tangent is x. This method I have applied to the results of Meyer, and the extreme points are shown at the points marked D and E in the accompanying cut.

Fig. 1.



The single experiment at zero centigrade gives the point C. All the other experiments furnish points scattered between D and E. The absolute values of the coefficient in these cases are: —

	$\tau =$	$\eta =$
C	273°.0	0.000168
D	293°.2	0.000198
E	287°.5	0.000178

For the line CD, $x = 2.3$; for the line CE, $x = 1.12$. This gives us

an idea of the value of these results in determining the variation of the viscosity with the temperature. We cannot say from them, whether this variation is proportional to the first or second power of the absolute temperature. Even the results published in the fifth paper, which was to determine this law, are insufficient. In the first series of these results, shown upon the curve by the extreme lines *NS* and *TS*, we see that the exponent representing the law of variation with the temperature varies from $x = 0.21$ for line *NS* to $x = 0.69$ for line *TS*, a variation even greater than in the results previously discussed. All the other observations give points intermediate between *N* and *T*. The second series furnishes little better data; and the third series, from determinations with oscillating plates, are not sufficiently complete for discussion in this way. They, however, afford no greater satisfaction.

Puluj has used the method of transpiration for some measurements of this law, and his results appear in the Sitz'ber. Wien. Acad. of 1874, lxix., 287. The results which he has obtained appear rather more concordant than those of Meyer, but still show considerable disagreement. Upon the above cut, the lines *OP* and *OQ* show the extremes of these results as obtained by a discussion of his experiments. These lines do not represent the greatest variations between successive results in the same series, but the extreme variation between the mean results of various series. For *OP*, $x = 0.65$; for *OQ*, $x = 0.47$. It will thus be seen that these results are more concordant than the different series of Meyer: they are not, however, completely satisfactory.

Later than these we have a brief notice of some experiments by von Obermayer, in the Phil. Mag., xlix., 332, 1875, in which he states that he has obtained results "which confirm those of Meyer's experiments in a perfectly satisfactory manner." He states Meyer's results as furnishing the exponent $\frac{3}{4}$ for the variation of η with the absolute temperature; whence we must conclude that this number expresses the result at which he has arrived.

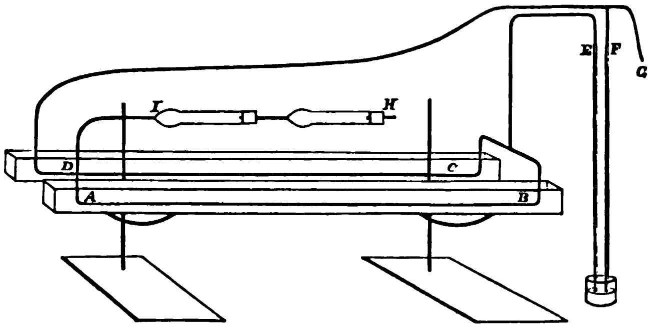
What value now are we to place upon these results, and which is the true one? Maxwell has given $x = 1$; Meyer, $x = \frac{3}{4}$; Puluj, $x = \frac{2}{3}$; von Obermayer, $x = \frac{3}{4}$. The first two values, $x = 1$ and $x = \frac{3}{4}$, we can hardly accept as certain, from the considerations previously shown. The value given by Puluj of $x = \frac{2}{3}$ is undoubtedly somewhat greater than is warranted by his results. Of the remaining experiments we cannot judge, since they have not yet appeared in full, so far as I have been able to ascertain.

The importance of this question in its bearing upon the kinetic

theory, as well as from its prominent place among the phenomena of gases, renders it very desirable that we should know the true law.

In endeavoring to arrange some new form of apparatus for a more accurate study of this law, the idea of a differential arrangement was suggested to me by Professor Pickering. This has been the origin of the following method. Two glass capillaries, *AB* and *CD*, were placed side by side, each in a tin trough to contain a bath to regulate the temperature of the gas. Air-tight glass and rubber connectors extended from *G* to the gauge *F*, and to the end *D* of one capillary. The ends *B* and *C* of the capillaries were connected with the gauge *E* by means of a T joint of glass. The end *A* of the second tube communicated with the external air through the chloride of calcium tubes *H* and *I*. The size of the connectors at the ends of *AB*

Fig. 2.



and *CD* was sufficient to allow the gas to assume the temperature of the bath. The tube at *G* was connected with a large flask, from which the air was continuously exhausted by means of a Richards' jet aspirator. The size of this flask rendered the pressure constant in spite of slight variations in water pressure. An inspection of this arrangement will show that when the flask is exhausted, and a vacuum produced at *G*, the air will enter at *A* under the atmospheric pressure, and will pass with constantly diminishing pressure to *G*; so that, at any intermediate point, as the junction of the two tubes at *BC*, we shall have a pressure intermediate between the two extremes. It will also be seen that the same volume of air is successively transpired through *AB* and *CD*; providing that there be no leak, which was carefully guarded against by making all the joints about *C*, *B*, and *E* — which were the only ones that affected the results — as tight as possible. By the two baths we may have the gas transpired successively through *AB* and

CD, either at the same or at different temperatures. Now, if we denote by V_1, R_1, λ_1, η_1, &c., the volume of gas transpired by AB, the radius and length of AB, and the coefficient of viscosity of the air passing through it, while V_2, &c., represent the same quantities for CD; also, if p_1, p_2, p_2, p_3 represent the pressure of the gas at A, B, C, and D respectively as obtained from the gauge and barometer readings; then from (1) we may write,

$$V_1 = \frac{\pi R_1^4 t_1}{8\eta_1\lambda_1} \cdot \frac{p_1^2 - p_2^2}{2p} \qquad (2.)$$

and

$$V_2 = \frac{\pi R_2^4 t_2}{8\eta_2\lambda_2} \cdot \frac{p_2^2 - p_3^2}{2p} \qquad (3.)$$

But if both baths are at the same temperature $V_1 = V_2$ if $t_1 = t_2$, and $\eta_1 = \eta_2$, whence we may write,

$$\frac{R_1^4\lambda_2}{R_2^4\lambda_1} = \frac{p_2^2 - p_3^2}{p_1^2 - p_2^2} \qquad (4.)$$

Also in general it will be seen from the nature of the apparatus that $\frac{V_1}{1+a\delta_1} = \frac{V_2}{1+a\delta_2}$, where δ_1 and δ_2 represent respectively the temperatures at which V_1 and V_2 are transpired. Hence

$$\frac{\eta_1}{\eta_2} = \frac{R_1^4\lambda_2}{R_2^4\lambda_1} \cdot \frac{p_1^2 - p_2^2}{p_2^2 - p_3^2} \cdot \frac{1+a\delta_2}{1+a\delta_1} \qquad (5.)$$

From equation (5) it will be seen that, in order to determine with this apparatus the ratio $\eta_1 : \eta_2$, between the coefficients of viscosity in the two tubes when the temperature of these is δ_1 and δ_2 respectively, we have only to know the ratio of the dimensions as expressed by $\frac{R_1^4\lambda_2}{R_2^4\lambda_1}$, and to measure p_1, p_2, and p_3 by reading three mercury columns. Also we can obtain a value of $\frac{R_1^4\lambda_2}{R_2^4\lambda_1}$ from readings of the gauges when $\delta_1 = \delta_2$, which needs only to be corrected for expansion of the glass to be used directly in equation (5). The whole process is thus reduced to the simple matter of reading columns of mercury, no measurements of volumes of gas being necessary. The nature of the correction of R and λ for temperature appears by putting into the above formulæ in which these values are supposed to be for 0° C, the coefficients of expansion of the glass $= A$; we thus get from (5): —

$$\begin{aligned}\frac{\eta_1}{\eta_2} &= \frac{R_1^4(1+A\delta_1)^4\lambda_2(1+A\delta_2)}{R_2^4(1+A\delta_2)^4\lambda_1(1+A\delta_1)} \cdot \frac{p_1^2 - p_2^2}{p_2^2 - p_3^2} \cdot \frac{1+a\delta_2}{1+a\delta_1} \\ &= \frac{R_1^4(1+A\delta_1)^3\lambda_2}{R_2^4(1+A\delta_2)^3\lambda_1} \cdot \frac{p_1^2 - p_2^2}{p_2^2 - p_3^2} \cdot \frac{1+a\delta_2}{1+a\delta_1}\end{aligned} \qquad (6.)$$

Lest, however, an error might occur in the last reduction from a difference between the coefficient of expansion of the bore of a capillary tube and of its lineal expansion, I have carefully measured both, and find that the coefficient for the bore is 0.0000075, while for the linear expansion I find 0.0000080 per degree centigrade, a difference too slight to affect the results in my use of it; I have thought it best to use the value 0.0000075 as it entered in the fourth power, while the other entered only in the first power. The tubes used have also been calibrated to insure the selection of those of uniform bore, and their dimensions have been accurately measured by mercury and a micrometer screw. The dimensions of the two tubes used in the experiments to be described, were, for tube No. I., $\lambda = 1272.3$ mm., $R = 0.1098$ mm.; for tube No. II., $\lambda = 1274.1$ mm., $R = 0.1115$ mm.

To make an experiment with this apparatus, it is merely necessary to start the jet of water and allow the exhaustion to proceed until the mercury columns in F and E have come completely to rest. Readings are then taken of the heights of these columns by means of a cathetometer from a steel scale placed beside the gauges. The reading of the barometer corrected for instrumental error gives the pressure at A. All these are reduced to the freezing point, and E and F are corrected for capillarity by the tables of Delcros. The temperature of the baths is also taken by thermometers in various positions in the troughs. This must be kept constant throughout the experiment, and I have, therefore, principally used the temperatures of melting ice and boiling water. In the experiments of which the following table gives the results, advantage has been taken of the four methods of checking the results of one experiment by another, by reversing the direction of flow of the air through the tubes and heating alternately, in each case, first one and then the other trough. In the table, column first gives the number of the experiment; column second, the direction of flow of the air, which entered at the tube whose number is first given and passed out from the other; columns three, four and five give the pressures at A, B and D respectively; columns six and seven show the temperatures in centigrade degrees of the baths around tubes I. and II. respectively; column eight shows the values of the ratio $\frac{R_1^4 \lambda_2}{R_2^4 \lambda_1}$ at different temperatures; column nine, the values of $\frac{\eta_1}{\eta_2}$, *i.e.* of η at the higher to η at the lower temperature; column ten shows the values of the exponent x in the equation $\eta = c\tau^x$. This is the quantity which it was the object of the experiments to obtain.

No.	Dir.	p_1	p_2	p_3	$T_{I.}$	$T_{II.}$	$\frac{R_1{}^4 \lambda_2}{R_2{}^4 \lambda_1}$	$\frac{\eta_1}{\eta_2}$	x
		m. m.	m. m.	m. m.					
1	I.-II.	759.9	525 2	16 3	17°0	17°0	0.912		
2	"	"	549.3	17.1	17.0	47.5		1.083	0.799
4	"	759.8	525 6	18 0	15.1	15.1	0.916		
5	"	"	584.4	18.9	"	"	0.921		
6	"	765.7	550.9	18.6	17.8	17 8	0.934		
7	II.-I.	"	490 7	17.7	17.5	99.0		1.212	0.776
8	"	"	491.2	17.6	17.5	99.5		1.206	0.755
9	"	"	490.0	17.3	17.5	99.8		1.215	0 780
11	"	755.2	467.8	20.4	0.0	100.0		1.272	0.771
12	"	"	468.4	19.4	"	"		1 267	0.757
13	"	"	467.9	19.6	"	"		1.271	0.768
14	"	"	467 7	19.3	"	"		1.273	0.773
16	"	"	544.2	20 7	0.0	0.0	0.927		
17	I.-II.	756.7	525.3	23.4	"	"	0.928		
18	"	"	594.8	21.5	0.0	100.0		1.277	0 782
19	"	761.4	529 1	16.1	100.0	100.0	0.933		
20	"	762.0	530.2	16 7	"	"	0.937		
21	"	763.1	452.2	18.5	100.0	0.0		1.259	0.738

In the calculation of the ratio $\frac{\eta_1}{\eta_2}$ of this table, the value of $\frac{R_1{}^4\lambda_2}{R_2{}^4\lambda_1}$ used was the mean of that obtained from experiments 16 and 17, after correcting for temperature. The agreement of these two values within 0.1 per cent is a test of the accuracy of the method, as the two experiments were made on different days, and the direction of the current was reversed. It will be seen that the value of this quantity increases slightly with the temperature, as we should expect from the slight difference in size of the two tubes used. The values of x will be seen to agree quite closely, with the exception of experiments 2 and 21. I have treated these results in the same manner as those of Meyer, and the result is shown on Fig. 1.

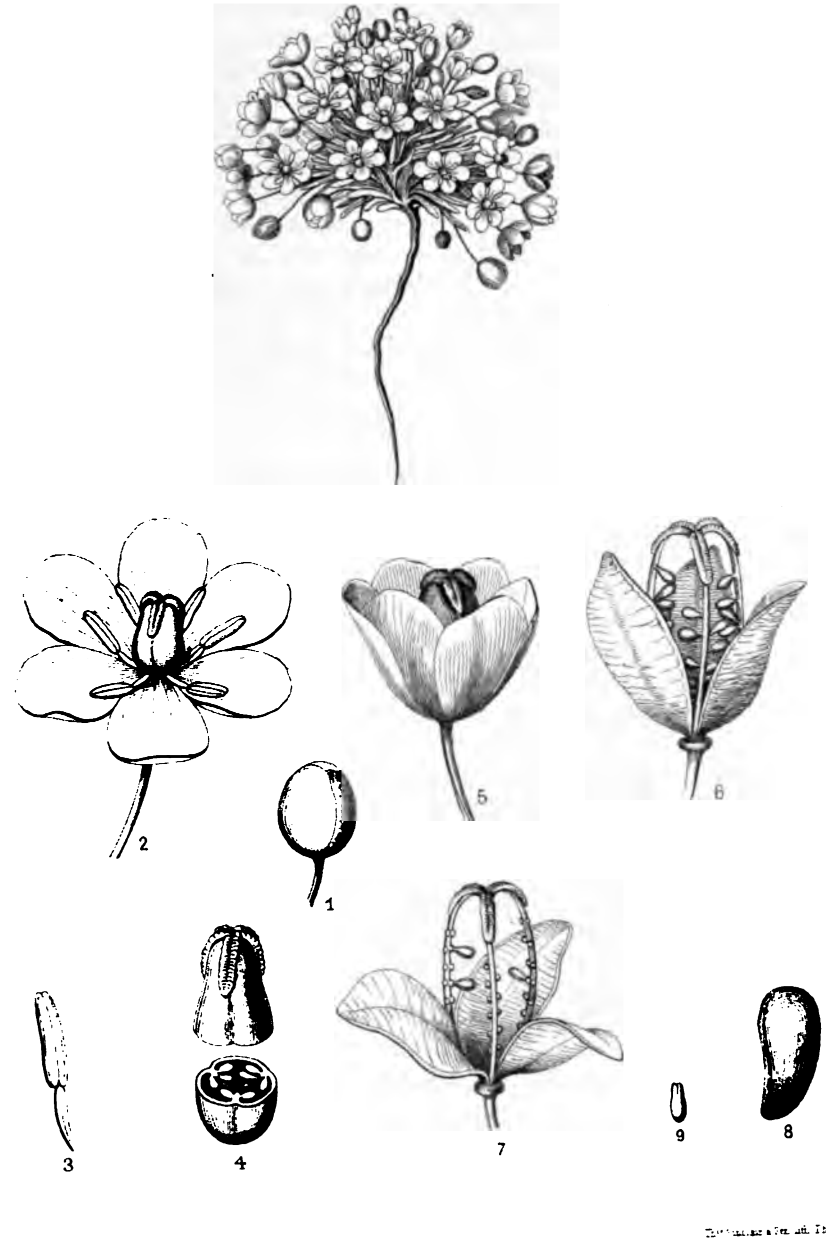
The point A is plotted from experiment 18, and B from 21; so that the lines AC' and BC' show the greatest variation in nine out of ten determinations, while the majority of these lie so close together as not to be capable of clear representation between A and B. The point C' has been raised from C for distinctness. Experiment 2 would indicate a deviation from the straight line; but I do not regard this as a perfectly reliable determination. More experiments are needed between 0° and 100° to establish the law.

In order to compare these results with those of Meyer, I have been obliged to assume his value of $\eta = 0.000168$ at 0.° C. as a starting-point, since the apparatus which I have used does not give absolute values of the coefficient of viscosity, but only ratios. It would appear, however, that the great concordance among the results thus far obtained would warrant its application to absolute measurements, for

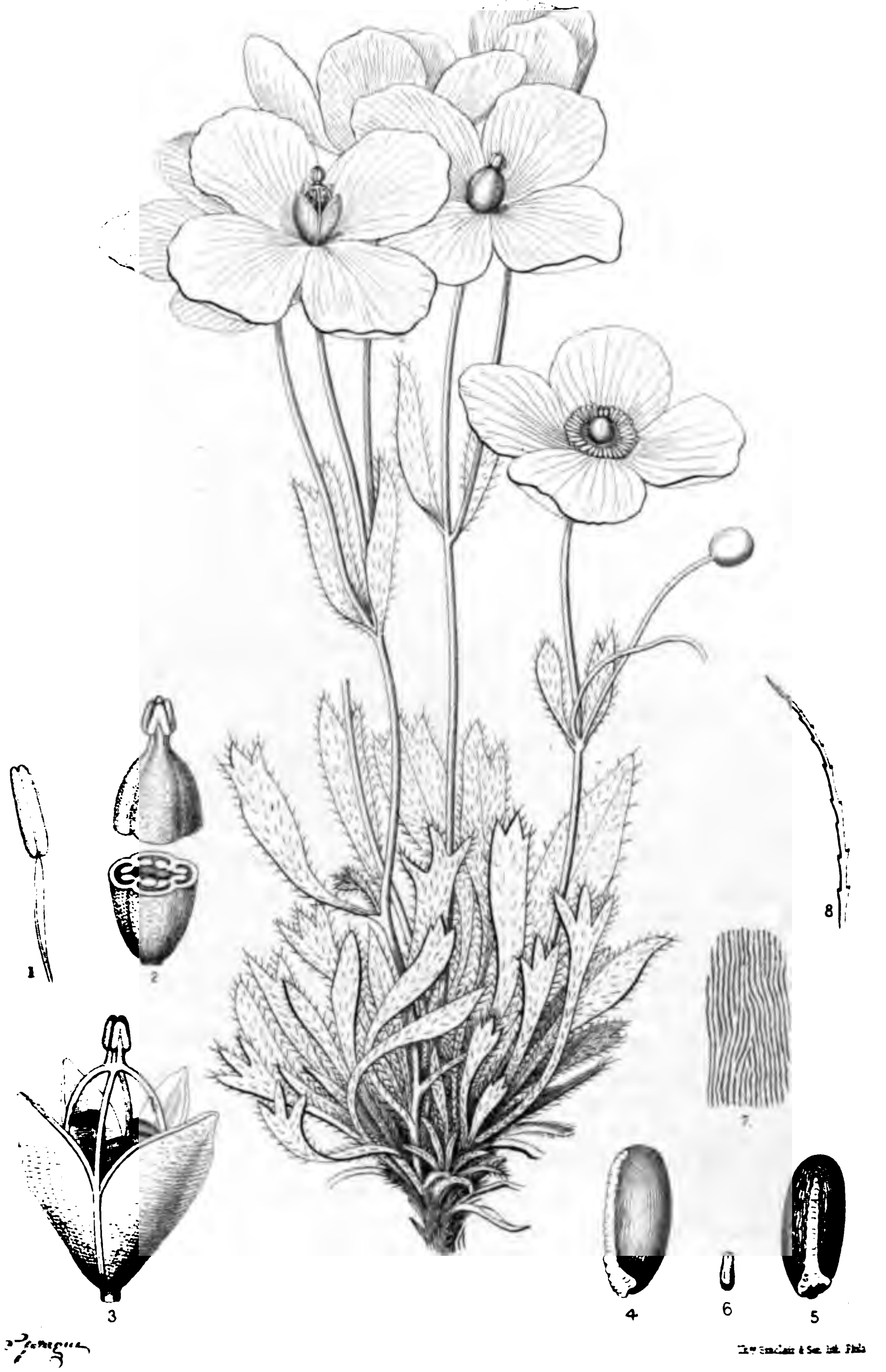
which it would only be necessary to measure the volume of the gas transpired in a known time. These, with experiments upon other gases, and also upon the validity of Poiseuille's law, I hope to be able to accomplish. The many points of superiority of this apparatus, and the excellence of these preliminary results, would seem to indicate more accurate determinations than others preceding them.

As a result of these experiments, it would appear that the viscosity of air increases proportionally to the 0.77 power, nearly, of the absolute temperature between 0° and 100° C. This value corresponds quite closely to the $\frac{3}{4}$ power, and we might infer that this was the value of x towards which the experiments pointed; but as I feel assured that further experiments will furnish still more concordant results, I should be unwilling to accept 0.75 until these had been performed. The general agreement of my results with the numbers of Meyer and von Obermayer would seem to point to the fact that the value of x cannot be as great as unity, and is probably about 0.75.

Plate I.



Canbya Candida.



Arctomecon Californicum.

V.

CONTRIBUTIONS TO THE BOTANY OF NORTH AMERICA.

By Asa Gray.

Presented June 13, and October 11, 1876.

1. *Characters of Canbya (n. gen.) and Arctomecon.*

WITH TWO PLATES.

CANBYA, Parry, nov. gen. *Papaveracearum.*

Sepala 3, caduca. Petala 6, obovata, diu persistentia, demum scariosa, capsulam obvolventia. Stamina 6–9: filamenta antheris oblongo-linearibus breviora. Ovarium subglobosum: placentæ 3, nerviformes, multiovulatæ: stylus nullus: stigmata 3, oblongo-linearia, reflexo-divaricata, ovario adpressa, *placentis superposita,* facie superiore (interiore) prorsus papillosa. Capsula ovoidea, membranacea, a vertice ad basim trivalvis, valvis placentas filiformes cum stigmatibus persistentes nudantibus. Semina plurima, elongato-oblonga, parum arcuata; testa lævissima nitida; rhaphe haud prominula nuda. Embryo prope basim albuminis minimus, cylindraceus. — Herbula annua, glabra, parum uncialis; foliis alternis linearibus integerrimis subcarnosis cum ramis brevissimis cæspitoso-confertissimis; scapis perplurimis filiformibus (semipollicaribus) unifloris; petalis læte albis.

Canbya candida, Parry. South-eastern California, in sandy soil on the Upper Mohave River, Dr. E. Palmer, May 18, 1876 (in flower and fruit). — This charming little winter-annual is one of the discoveries made by the botanical party, consisting of Doctors Palmer and Parry and Mr. Lemmon, which passed last winter in S. E. California and adjacent districts. Dr. Parry, who immediately recognized its botanical interest, proposed to dedicate the plant to our common friend and worthy fellow botanist, William M. Canby, Esq., of Wilmington, Delaware; and I have peculiar pleasure in carrying this proposition into effect.

The plant is of most diminutive size, but of much botanical interest and no small beauty. From the *Sagina*-like tuft of foliage at the surface of the ground rises a multitude of tiny peduncles or scapes, each tipped with a bright white flower which lasts for many days; the petals (barely two lines long) opening at sunrise, and at sunset closing over the ovary, and at length permanently over the capsule, into a globular form, which the discoverer likens to a pearl. The most unexpected anomaly in this order of a persistent (instead of caducous) corolla is shared by *Arctomecon*, native of the same district, as Dr. Parry himself ascertained upon rediscovering that exceedingly rare plant in the spring of the preceding year. There are other Papaveraceous plants which hold their petals for a day or two, notably *Sanguinaria* in which they open and close for four or five days before falling; but in these two peculiar genera they become scarious, remaining permanently in *Arctomecon*, and up to the full maturity of the capsule in *Canbya*.

The two genera, although closely related, differ in some important points of floral structure as well as in aspect. The most marked difference is in the stigmas, which in *Canbya* are perfectly sessile, long, entire, and divergent to the utmost, so that their backs are closely applied to the surface of the rounded top of the ovary, directly over the placentæ, and the upper or ventral face papillose-stigmatic; while *Arctomecon* has a short style, the indistinct lobes of which bear extrorse and two-lobed stigmas, which are alternate with the placentæ, and are closely appressed or even partly united in a kind of head. The capsule of the one is membranaceous and dehiscent to the base; of the other, coriaceous and apparently dehiscent only to the middle. The seeds and the stamens are likewise different. The wretched figure of *Arctomecon* in Fremont's Report exhibits none of these characters, and it led Bentham and Hooker to conjecture that plant might be only a *Papaver*, allied to *P. nudicaule*. Dr. Parry's specimens were received in time for a partial reconstruction of the generic character in the Botany of California; but the position of the stigmas and the presence of a prominent crest of the seed have not before been noticed. A full character of that genus is therefore here given, along with that of *Canbya*.

ARCTOMECON, Torr.

Sepala 2, raro 3? Petala 4, latissime obovata, persistentia, demum tenuiter scariosa. Stamina indefinite plurima: filamenta sursum parum dilatata, antheris brevi-linearibus longiora. Ovarium obovoideum:

placentæ 3–6, nerviformes, pluriovulatæ: stylus brevissimus, sublobatus, lobis erectis pl. m. coadunatis stigmata *placentis alterna* cordato-biloba capitato-conferta extrorsum gerentibus. Capsula obovoidea, subangulata, apice breviter 3–6-valvis; valvis coriaceis a placentis filiformibus stylo brevissimo persistente connexis solutis. Semina pauciuscula, majuscula, oblonga, recta; rhaphe cristata; testa tenuiter lineolata, crista ad hilum carunculato-dilatata sursum sensim angustiore. Embryo cylindraceus, albumine ⅓ brevior. — Herba nana, ut videtur biennis; foliis alternis (summisve nunc oppositis) cuneatis vel spathulato-lanceolatis apice 2–5-dentatis seu inciso lobatis barbato-setosis; pedunculis subumbellatis nunc scapiformibus unifloris; floribus majusculis albis.

Arctomecon Californicum, Torr. in Frem. Rep. ed. 2, 312, t. 2; Parry in Am. Naturalist, ix. 139 & 268; Brewer & Watson, Bot. Calif. i. 21.

The accompanying plates illustrate the two genera: —

PLATE I. CANBYA CANDIDA. Plant of the natural size.

Fig. 1. Flower bud, enlarged.
2. Expanded flower, enlarged.
3. Stamen, more magnified, as are all the following details.
4. Base of ovary showing cross section, and upper part, with the stigmas.
5. Mature capsule with the investing persistent petals.
6. Dehiscent capsule, with seeds.
7. Same, the seeds fallen.
8. Seed, more magnified.
9. Embryo, on the same scale.

PLATE II. ARCTOMECON CALIFORNICUM. Natural size: the details variously magnified.

Fig. 1. A stamen.
2. Pistil transversely divided.
3. Dehiscent capsule.
4. Seed, lateral view.
5. Same, with crest anterior.
6. Embryo, equally magnified with the seed.
7. Portion of surface of seed, more magnified, to show the lineolation.
8. Portion of bristle from a leaf.

2. *Characters of New Species, &c.*

ISOPYRUM STIPITATUM. Perenne: radicibus fasciculatis: caulibus spithamaeis teretibus apice 1–2-foliatis 1–2-floris: foliis radicalibus tricaulinis saepius bi-ternatisectis, petiolulis primariis secundariisque elongatis, segmentis ultimis foliolisve sessilibus nunc confluentibus lineari-oblongis integris vel cuneatis trifidis: pedunculo sub flore parvo incrassato; sepalis 4–5 oblongis: petalis nullis: staminibus parum 10, filamentis subulato-complanatis: folliculis totidem oblongis utrinque obtusissimis vix venosis 3–4-spermis longiuscule stipitatis. — Northern California, near Yreka, Siskiyou Co., April, 1876, under *Ceanothus* and Oak bushes. Rev. E. L. Greene. A most distinct species; with flowers much smaller than those of *T. occidentale*, of which it has the habit, although larger than those of *T. fumarioides*. Stipe of the fruit nearly a line long.

NASTURTIUM TRACHYCARPUM. E radice annua? erectum, ramosum (pedale), fere glabrum; foliis lyrato-subpinnatifidis; racemis laxis; floribus albidis; petalis spathulatis sepala antherasque oblongo-sagittatas parum superantibus; siliquis oblongo-linearibus (lin. 4–5 longis) papilloso-asperatis in pedicello rigido mox recurvato curvato-adscendentibus stylo longo subulato superatis. — S. W. Colorado, on the San Juan, &c., T. S. Brandegee, in Hayden's Expedition, 1875. The rhachis of the raceme and the stout pedicels are more or less studded with the small rough papillæ which abound on the pod and suggest the name for the species, which is a very distinct one.

LEPIDIUM DICTYOTUM, Gray, var.? ACUTIDENS, siliculis magis ovatis, dentibus longioribus deltoideo- immo subulato-triangulatis omnino acutis. — California at Yreka, E. L. Greene.

CLAYTONIA BULBIFERA. *C. Sibiricæ*, L. (*alsinodei*, Sims) similis, sed bulbillis radicalibus bulboso-confertis perennans; racemis elongandis folioso bracteatis; bracteis spathulatis seu lineari-oblongis; sepalis latioribus, fructiferis dilatatis. — Scott Mountains, Siskiyou Co., California, E. L. Greene. Also received from some other Californian collectors, but without the bulbiferous base. To the acute observation of Mr. Greene we are also indebted for an indication of the characters which appear to demand the re-establishment of C. *parviflora*, Hook. and perhaps one or two other species.

ASTRAGALUS COLLINUS, Dougl., var. CALIFORNICUS, leguminibus cum stipite sesquipollicaribus purpureo-marmoratis. — Yreka, California, E. L. Greene.

ASTRAGALUS FLAVUS, Nutt., var. CANDICANS. Canescens; pedun-

culis subscapiformibus. — Near Richfield, Utah, at 5,900 feet, in loose ashy soil, Lester F. Ward, in Powell's Expedition. Apparently a form of Nuttall's species, but more condensed as well as hoary, and with somewhat the aspect of *Oxytropis*. The specimens supply mature fruit, which is wanting in Nuttall's specimens. The legume is one-celled, with little or no introflexion or thickening of the dorsal suture; while externally the ventral suture has a very salient ridge and a shallow and broad groove each side of it, somewhat in the manner of *A. bisulcatus*.

ASTRAGALUS WARDI. *Inflati:* perennis? viridis, undique fere glaber; caulibus erectis ultrapedalibus foliosis: stipulis triangularibus vel subulatis parvulis: foliolis multijugis angusto-oblongis obtusis retusisve (lin. 3–4 longis); pedunculis filiformibus folio brevioribus laxe racemoso-10–15-floris; floribus mox pendulis; calycis dentibus subulato-setaceis tubo breviter campanulato æquilongis; corolla alba nunc purpurascente lin. 2–3 longa; legumine vesiculoso ovato acuto recto subæquilatero haud stipitato glaberrimo purpureo-marmorato ⅜-pollicari. — Sevier Co., Utah, on the edge of Aquarin's Plateau, at 8,700 feet, Lester F. Ward, in Powell's Expedition.

ASTRAGALUS NEWBERRYI. *Scytocarpi:* subcaulescens; caudicibus in radice elongato profundo brevissimis confertis; foliis argenteo-sericeis; foliolis 3–7 nunc lato- nunc angusto-obovatis approximatis (lin. 4–6 longis); pedunculis brevibus vel brevissimis paucifloris; calyce cylindraceo sericeo, dentibus tubo plus dimidio brevioribus; corolla ochroleuca ¾-pollicari, unguibus elongatis; legumine chartaceo ovato inflato villoso pollicari uniloculari, acumine lato lateraliter compresso subincurvo, suturis haud incrassatis nec intus nec extus prominulis. — *A. Chamæleuce*, Gray in Bot. Ives Colorad. Exp. 10, quoad pl. Newberry. — On the frontiers of Utah and Arizona, Prof. Newberry. Cañon east of Glenwood, Sevier Co., Utah, at 7,000 feet, Lester F. Ward, in Powell's Expedition, 1875. Having now the fruit, it is clear that Newberry's plant, in flower only, is not the same as *Phaca pygmæa*, Nutt., which should retain the name of *A. Chamæleuce*, while this may take that of the original discoverer.

ASTRAGALUS PATTERSONI. *Scytocarpi:* robustus, 1–2-pedalis, adpresso-puberulus, nunc glabellus; foliolis 6–10-jugis oblongis crassiusculis (semipoll. ad pollicem longis): pedunculis racemoso-plurifloris folium æquantibus vel superantibus; floribus mox pendulis ultra-semipollicaribus; calycis dentibus setaceo-subulatis tubo cylindraceo dimidio brevioribus; corolla alba; carina apice nunc purpurascente; legumine ovali crasso-coriaceo inflato glabro (sæpius pollicari) polyspermo, basi intra calycem abrupte contracta substipitiformi, suturis nec intrusis nec

extus prominulis. — Foot-hills of Gore Mountains, Colorado, H. N. Patterson. Rio McElmo, Southwestern Colorado, T. S. Brandegee, in Hayden's Expedition, 1875. Utah on Dirty-Devil River, and near Richfield, L. F. Ward, in Powell's Expedition, 1875. The two last in fruit only; while the fruit of Mr. Patterson's plant (who alone has found the flowers) is decidedly smaller, sometimes little over half an inch long.

ASTRAGALUS SUBCOMPRESSUS. *A. racemoso* sect. *Galegiformium* admodum similis; dentibus calycis brevioribus; corolla ochroleuca; legumine falcato lateraliter compresso intus septo completo bilocellato, sulco dorsali angusto subclauso, stipite e calycis tubo haud exserto. — S. W. Colorado, common at the altitude of 7,000 feet, T. S. Brandegee, in Hayden's Exped. 1875. Legumes an inch and a quarter or only an inch long, 2½ to nearly 3 lines wide, the well-developed ones decidedly falcate; the partition about twice the length of the depth of the groove, which in the cross-section of the well-grown pod before dehiscence is oval and almost closed.

ASTRAGALUS HAYDENIANUS. *A. bisulcato* affinis, minor; pube magis cinerea; spica elongata virgata; floribus multo minoribus (lin. 3–4 longis); calycis dentibus subulatis tubo multo brevioribus; corolla alba, carina apice purpureo tincta; legumine ovali utrinque obtusissimo venis transversis ruguloso 6–7-ovulato 2–4-spermo, facie ventrali late profundeque impressa sutura costæformi valde prominente percursa, stipite calycem haud superante. — Common in S. W. Colorado, at the altitude of 7,000 feet, T. S. Brandegee, in Hayden's Expedition, 1875. Also banks of Grand River in Middle Park, H. N. Patterson. "Plant 2 or 3 feet high." Dedicated to Dr. F. V. Hayden, the Director of the expedition in which it was collected, and the distinguished explorer and surveyor of our whole Rocky Mountain district.

ASTRAGALUS TRICARINATUS. *A. arrecto* subsimilis, 1–2-pedalis; foliolis plurimis parvis (lin. 3–4 longis) ovalibus obovatisve emarginatis crassiusculis supra glabellis subtus cano-puberulis secus rhachin elongatam sat rigidam sparsis vel remotiusculis; racemis sparsifloris longe pedunculatis; bracteis ovato-subulatis minimis; floribus subpatentibus; calycis nigro-hirsutuli tubo brevi-campanulato pedicello æquilongo dentibus subulatis parum longiore; corolla ochroleuca seu flavida (semipollicem longa); ovario glaberrimo; legumine lato-lineari, maturo arcuato ultrapollicari coriaceo bilocellato quasi tricarinato, nempe dorso inter carinas obtusas late sulcato, ventre acutissime carinato, faciebus concavis, sectione transversa late Y-formi, stipite calycis tubo breviore. — White Water, San Bernardino Co., California, Parry, 1876.

Astragalus humillimus. Cæspitoso-depressus, condensatus; caudice lignescente; caulibus vix pollicaribus stipulis scariosis coalitis imbricato-tectis petiolis persistentibus hystricosis; foliolis 3–5-jugis oblongis canescentibus margine revolutis lineam longis demum deciduis; pedunculis brevibus 1–3-floris; calycis dentibus subulatis tubo oblongo-campanulato dimidio brevioribus; corolla pallida: legumine ovato coriaceo albido-pubescente parvo (lin. 2 longo) uniloculari 9-ovulato fere monospermo, suturis extus prominulis. — Flat rocky grounds on the Mesa Verde, S. W. Colorado, T. S. Brandegee, in Hayden's Expedition, 1875. Habit of *A. jejunus*, Watson, but much more dwarf and condensed, not rising more than 2 or 3 inches above the ground, and often choked in drifting sand. Persistent petioles and rhachis only an inch long, more rigid and spinescent than those of *A. jejunus*, which are also persistent: the pod decidedly different.

Lespedeza leptostachya, Engelm. in herb. Gray. Pube undique adpressa argenteo-canescens; petiolo petiolulo terminali longiore; foliolis linearibus; spicis paniculatis gracilibus sublaxifloris longiuscule pedunculatis; legumine calycem adæquante vel subsuperante. — Minnesota, T. J. Hale. Illinois, Bebb. Iowa, T. C. Arthur, Bessey. Has passed for *L. angustifolia*, from which its slender spikes and paniculate habit at once distinguish it. Our species of the group are difficult and need revision, with very ample materials to be studied with the attention which Maximowicz has bestowed upon the Asiatic species. *L. capitata*, Michx., should be known by its very short petioles, short-peduncled and globular heads of flowers, and legume much shorter than the calyx; *L. angustifolia*, Ell., by smaller and often oblong heads, on distinct and sometimes slender peduncles, and legumes hardly shorter than the calyx, the leaflets linear; *L. hirta*, by pubescence of stem perhaps always spreading, leaflets from orbicular to narrow oblong, petioles mostly slender, oblong spikes on elongated peduncles, and legume at maturity hardly shorter than the calyx.

Epilobium jucundum. *E. paniculato* affine; floribus multo majoribus thyrsoideo-paniculatis; calycis tubo ultra ovarium longe producto tubuloso-infundibuliformi; petalis læte purpureis late obcordatis semipollicaribus; antheris fere linearibus; stylo prælongo. — Scott Valley, Siskiyou Co., California, E. L. Greene, Aug. 28, 1876. A showy species, well worthy of cultivation, having flowers almost as large as those of *E. obcordatum*, and very numerous in a rather crowded panicle. The calyx beyond the ovary is half an inch long, more narrowly funnel-form than in *E. paniculatum*, the tubular part about equalling

the ovary; the petals are much broader as well as larger, and the anthers (of short-linear outline) fully twice longer.

GALIUM BRANDEGEI. Cæspitoso-depressum, parvum, glabrum, lævissimum; radicibus fibrosis; foliis quaternis obovatis vel spathulatis fere aveniis lin. 1–3 longis; pedunculis unifloris solitariis binisve nudis; flore albido semi-lineam longo; fructu lævi glabro. — Valley of the Rio Grande, New Mexico, on Los Pinos Trail, at 9,000 feet, Sept., 1875, T. S. Brandegee, in Hayden's Expedition. Spreading extensively over the barely moist ground, evidently perennial; the stems only 2 or 3 inches long. We have no other North American species much resembling this.

BRICKELLIA GREENEI. Subsesquipedalis, pube viscidissima; caulibus usque ad capitula solitaria ramos terminantia foliosis; foliis caulinis ovatis obtusis medium versus inæqualiter serratis basi subtruncatis brevissime petiolatis, ramealibus oblongis subintegerrimis, summis capitulum involucrantibus eoque brevioribus; involucro proprio multifloro, squamis linearibus acuminatis glabellis, extimis brevioribus tantum lanceolatis; acheniis ad angulos hirtellis.—Siskiyou Co., California, on the south fork of Scott River, E. L. Greene, Aug. 24, 1876. Cauline leaves an inch long, thinnish; those of the short and somewhat corymbose flowering branches barely half an inch long. Head three quarters of an inch long.

BIGELOVIA VASEYI. *Chrysothamnus:* depressa, glabra, lævis; caulibus e basi decumbente erectis spithamæis; foliis angustis spathulato-linearibus obtusis: capitulis corymboso-confertis plerumque sessilibus; involucro angusto oblongo subclavato 5-floro, squamis minus carinatis oblongis obtusissimis chartaceis, exterioribus apice crassiore viridulo; appendicibus styli obtusiusculis parte stigmatica lineari dimidio brevioribus; ovario glaberrimo. — Colorado, in Middle Park, Dr. Geo. Vasey, in Powell's Exped., 1868. Utah, on Aquariu's Plateau, at 9,000 feet, L. F. Ward, in Powell's Exped., 1875. Leaves an inch or less in length, a line or less wide. Heads in Vasey's specimens 4 lines long, in Ward's better developed ones are 5 or almost 6 lines long; the scales of the involucre less carinate and less prominently straight ranked than in the related species; the greenish tips also suggesting the *Aplodiscus* section.

SOLIDAGO SPARSIFLORA. *Virgaurea*, *Virgatæ:* scabrido-puberula; foliis inferioribus ignotis, superioribus floralibusque parvulis lanceolatis (lin. 6–12 longis); racemulis oligocephalis laxis laxeque thyrsoideis; involucri squamis linearibus puberulis apice viridulis acutiusculis; floribus radii circiter 10 ligulis parvulis, disci 4–5; acheniis sericeo-pubes-

centibus. — Arizona, near Camp Lowell, Sept., 1874. Rothrock, in Wheeler Expedition, 1874.

GYMNOLOMIA (HELIOMERIS) PORTERI. Annua, ramosa; foliis lanceolatis linearibusque plerisque alternis integerrimis margine inferne parce hispidis; capitulis cymoso-paniculatis, pedunculo gracili; involucro laxo e squamis anguste linearibus subfoliaceis fere uniseriatis ligulas subæquantibus; receptaculo alte conico; corolla disci fauce latissime campanulata lobis æquilonga, tubo abrupto brevi basi incrassato; stylo basi bulboso, ramis hispidulis appendice tenuiter subulata hispida terminatis; acheniis turgidis hispidulis calvis, marginibus ad apicem latum truncatum in umbonem parvum productis, areola parva vix annulata. — *Rudbeckia? Porteri*, Gray, Pl. Fendl. 83. Stone Mountain, Upper Georgia, Porter, Hendee, Ravenel, and later Engelmann and Canby, August and September.

PALAFOXIA FEAYI. Scabra; foliis oblongis lanceolatisque basi vel utrinque obtusis (pollicaribus); capitulis subcymosis; involucro e squamis linearibus obtusis floribus 2–3-plo brevioribus pedunculisque eglandulosis; corollæ fauce cylindracea lobisque breviusculis *P. linearifoliæ;* pappi paleis oblongis obtusis basi incrassatis achenio multoties corollæ tubo dimidio brevioribus. — S. Florida, Dr. William T. Feay, Dr. Chapman.

HULSEA PARRYI. Humilis; foliis plerisque radicalibus confertis spathulatis inæqualiter argute dentatis primum albo-lanuginosis; caulibus floriferis plurimis scapiformibus (spithamæis) gracilibus glabellis simplicibus monocephalis vel basi divisis bracteis paucis linearibus subulatisve instructis; capitulo pro genere parvo (semipollicem alto); involucro viscoso-pubescente, squamis lato-linearibus flores disci ligulasque paucas inconspicuas subæquantibus; pappi paleis oblongis parum erosis subæqualibus. — S. E. California, in the Mohave district, Dr. Parry, 1876. The flowers appear to be yellow, with tips disposed to turn to purple.

GAILLARDIA SPATHULATA. *G. acauli* spec. insigni peraffinis; caulibus spithamæis e caudice perenni multicipiti plurimis plerumque ramosis foliatis; foliis spathulatis integerrimis basi sensim attenuata sessilibus; pedunculo breviusculo, pappi paleis 9–11 oblongis longius aristatis, arista corollam disci mox superante. — S. Utah, in Rabbit Valley, at 7,000 feet, L. F. Ward, in Powell's Exped., 1875. Leaves, as in *G. acaulis*, thickish and firm; the larger a full inch long; the uppermost reduced to half or a third of an inch. Heads rather smaller than in *G. acaulis*, on a slender terminal peduncle of an inch or two in length. Disk-corollas 3 lines long.

TETRADYMIA COMOSA. *Lagothamnus:* lana gnaphaloidea dealbata, 3–4-pedalis; ramis ramulisque erectis; foliis sparsis linearibus planis (sæpe ultra-pollicaribus) cuspidato-mucronatis aut deciduis aut nonnullis in spinam modice induratam persistentem mutatis; fasciculis axillaribus nullis; capitulis ad apicem ramosum corymboso-cymulosis; cæterum fere *T. spinosæ.* — W. Nevada, Lemmon. S. E. borders of California, E. Palmer. Potrero, San Diego Co., D. Cleveland.

NEMACLADUS LONGIFLORUS. Foliis radicalibus magis cano-hirtis; corolla tubulosa sepalis æqualibus a basi fere discretis sublinearibus 3–4-plo longioribus, tubo fere integro; filamentis longius monadelphis; ovario fusiformi; capsula oblonga septo contrario subcompressa calyce libero plus duplo longiore; seminibus turgide ovalibus. — S. E. California, Wallace, Lemmon. A specimen of this, collected by Mr. Wallace (probably between Los Angeles and San Bernardino), has long been in our herbarium, but the characters have been noticed only now upon the coming of fine specimens collected recently by Mr. Lemmon. The flowers and fruit differ strikingly from those of *N. ramosissimus*, and call for emendation of the generic character. In the new species the calyx is actually free from the ovary and capsule, and 5-parted to the base, and the long and narrow capsule is 2-valved from top to bottom. It is very interesting to have a second species of this remarkable genus; but it throws no additional light upon its affinities.

LOBELIA LUDOVICIANA. Inter *L. paludosam* et *L. appendiculatam* quasi media, glabra, caule 2–3-pedali gracili folioso; foliis crassiusculis basi angustatis, superioribus lanceolatis acutis, inferioribus petiolatis, imis spathulatis obtusis; racemo nudo laxe 5–20-floro; floribus secundis horizontalibus puberulis; corolla cærulea semipollicari; calycis tubo fere hemisphærico, lobis ovato- seu (auriculis brevibus integris reflexis) cordato-lanceolatis tubo corollæ dimidio brevioribus capsula parum longioribus margine sæpius integerrimis; antheris majoribus superne hirsutis, apice imberbi. — In wet prairies, Western Louisiana, J. Hale; Texas, near Houston, Lindheimer.

LOBELIA FEAYANA. *L. Cliffortianæ* et *L. Berlandieri* affinis, glabra, annua; caulibus spithamæis ramosis diffusis tenellis; foliis ($\frac{1}{4}$–$\frac{1}{3}$-pollicaribus) obovatis vel rotundatis petiolatis repando-denticulatis, summisve spathulatis seu lanceolatis sessilibus; racemis nudis pedunculatis laxe 4–10-floris; pedicellis (lin. 2–4 longis) flori æquilongis bractea subulata 2–3-plo longioribus; calycis tubo capsulaque ($\frac{2}{3}$ infera) lato-obconicis, sinubus nudis, lobis subulatis tubo corollæ læte cæruleæ (parum lin. 2 longæ) dimidio brevioribus apicem liberum capsulæ vix superantibus; antheris glabris, brevioribus apice barbulatis; seminibus

oblongis, testa cellulosa. — Eastern and Southern Florida, Dr. Feay, Dr. E. Palmer, Mrs. Treat, &c.

ARCTOSTAPHYLOS CLEVELANDI. *A. bicoloris* quoad folia et tomentum sat similis, bipedalis; ramis longe crebreque foliosis; foliis subsessilibus oblongis sublanceolatis cuspidato-acuminatis supra mox glabratis nitidulis subtus albido-tomentulosis; racemis folioso-bracteatis; pedicellis bractea brevioribus flore duplo longioribus supra medium folioso-bibracteolatis; sepalis ovatis imbricatis tomentosis; corolla brevi-oblonga sub-urceolata (lin. 4 longa) albida multinervulosa; filamentis subulatis villosis; stigmate capitato; disco hypogyno ovarii glabri dimidium æquante: drupa ignota. — Potrero, San Diego Co., California, D. Cleveland, 1876. In flower Sept. 20.

RHODODENDRON CHAPMANII. *R. punctato* perquam similis; ramis rigidioribus erectis; foliis crassioribus minus petiolatis; floribus præcocioribus; corollæ infundibuliformis lobis ovatis tubo staminibus styloque brevioribus; seminibus anguste oblongis. — *R. punctatum* var. Chapm. Fl. 266. — Sandy pine barrens of W. Florida, Dr. Chapman.

CLETHRA, PYROLA, etc. The early view that the anthers of *Pyroleæ* are in normal position in the bud (in other words, that they are extrorse and the foramina basal), to which I reverted in the later editions of the Manual of Bot. N. U. States, upon some observations by the late Prof. H. J. Clark, must be adhered to. Baillon, indeed (in Adansonia, i. 194), states the contrary with much particularity, apparently from direct observation: "Chaque loge se termine en un tube à pore de dehiscence apical. L'anthère est introrse quand le pore est en haut; elle est, par conséquent, extrorse quand le pore regarde en bas. Le filet est dans son jeune âge rectiligne et dressé. Plus tard il s'alonge beaucoup et s'infléchit en se moulant sur la convexité de l'anthère. Lors de l'épanouissement complet, il se redresse une seconde fois en totalité." I can affirm, on the contrary, that the anthers are developed from the first in this extrorse position, and undergo no inversion in the bud; indeed, the anther is well formed and the basal horns plainly recognizable before the filament has an appreciable length, at least such as would allow the former to execute the supposed "mouvement de bascule."

Clethra agrees with the *Pyroleæ* in having primarily extrorse anthers, as well as in the simple pollen and completely polypetalous corolla. These characters are fully equal in value to those upon which De Candolle and others break up the original *Ericaceæ* into separate orders, and, if apprehended by Bentham and Hooker, might have led them to give ordinal rank to the *Pyroleæ*, appending *Clethra*, which they

almost exclude from *Ericaceæ*. Much preferring to retain the order as a great whole, I would combine *Clethra* and the tribe *Pyroleæ* into the third suborder, *Pyrolineæ*.

GALAX APHYLLA, Linn. The name first appears in the first edition of the Species Plantarum, p. 200, in 1753. Neither generic nor specific name has any fitness; the herb is not milky, nor is it leafless, except as to the scape. The plant in view, the *Anonymos s. Belvedere*, of Clayton, is recognizable by the good generic character in the first edition of the Flora Virginica, and from Clayton's herbarium. The generic character of *Galax* first appears a year later, in the 5th edition of the Genera Plantarum, and it is, as has been noted, utterly incongruous with Clayton's plant, to which Linnæus meant to apply it. This generic character Linnæus copied from Mitchell's Nova Plantarum Genera, viz., from his *Viticella*, merely substituting the name of *Galax*. Consequently not a word of the Linnæan generic character is applicable to *Galax aphylla*, Linnæus's only species; wherefore it is not surprising that Andrews, Richard, and Ventenat should have respectively described that plant under other generic names. Although the contradiction was long ago pointed out, still most authors, down to Endlicher, De Candolle, and later, have followed Linnæus in citing *Viticella* as a synonym of *Galax*. Gronovius, in the second edition of the Flora Virginica, was evidently struck by this total discrepancy; and he covered it in a curious way, by omitting altogether the correct character of Clayton's plant, as printed in the original edition. It was reserved for Mr. Bentham to divine what Mitchell's *Viticella* really is, viz., *Hydrophyllum appendiculatum*, to which the name of *Galax* etymologically is equally inapplicable. See Benth. & Hook. Gen. ii. 827.

STEIRONEMA, Raf. in Ann. Gen Phys. Brux. vii. 192 (1820). Genus between *Trientalis* and *Lysimachia*, distinguished from both by the presence of staminodia (the rudiments of the other series of stamens) between the fertile filaments, and by the æstivation of the corolla, in which each division is separately involute around, or even convolutely enwraps the stamen before it. The latter character, which I have recently ascertained, is not alluded to by Baudo in his index of the caulescent *Anagallideæ* (Ann. Sci. Nat. ser. 2, xx.), nor by Bentham and Hooker in the second volume of the Genera Plantarum, in which the æstivation of the corolla is first systematically employed in the arrangement of this order.* Following Bigelow (§ *Seleucia*) I had

* The tribe *Lysimachieæ* is characterized as having convolute (or "contorted") æstivation of the corolla; the *Primuleæ*, by quincuncially imbricated. This

long ago marked out *Steironema* as a subgenus; but this new particular warrants the complete separation.

The species are not easy to define, as they incline to run into each other. But they are on the whole tolerably well distinguished in the later editions of the Manual of the Botany of the N. United States. They are: —

S. CILIATUM. (*S. ciliata*, Raf. l. c.)

S. RADICANS. *Lysimachia radicans*, Hook. Companion to Bot. Mag. i. 177.

S. LANCEOLATUM. (*S. heterophylla*, Raf. & *S. florida*, Baudo, mainly.) *Lysimachia lanceolata*, Walt. Var. HYBRIDUM, the *L. hybrida*, Michx. Var. ANGUSTIFOLIUM, the *L. angustifolia*, Lam., and *L. heterophylla*, Michx.

S. LONGIFOLIUM. (*S. longifolia?* & *S. revoluta*, Raf.) The oldest specific name is *Lysimachia quadriflora*, Sims, Bot. Mag. t. 660, but that name is an inappropriate and deceptive one. *L. longifolia*, Pursh, is only a little later, and is unobjectionable.

FRAXINUS GREGGII. *Ornus*; fruticosa, glabra; ramis gracilibus teretibus; foliolis 3–7 angusto-spathulatis seu oblongo-obovatis obtusis obtuse paucidentatis vel integerrimis planis coriaceis fere aveniis sessilibus parvis, petiolo inter foliola alato-marginato; samara oblongo-lineari apice retusa stylo brevissimo apiculata. — *F. Schiedeana* var. *parvifolia*, Torr. Bot. Mex. Bound. 166. — S. W. Texas, and adjacent parts of Mexico, Gregg, Schott, Bigelow, Parry.

FORESTIERA NEO-MEXICANA. *F. acuminatæ* proxima; foliis minoribus (pollicaribus) spathulato-oblongis apice obtusis vel obtuse subacuminatis brevi-petiolatis; floribus fœmineis fasciculatis (haud paniculatis); calyce minuto subpersistente; drupis brevi-oblongis vel ovoideis obtusis. — *F. acuminata* var. *parvifolia*, Gray, Proc. Am. Acad. iv. 364. — New Mexico, Fendler, C. Wright, Palmer, Brandegee.

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holds well, the anomalous case of *Steironema* excepted, yet with somewhat of the gradations which are almost everywhere apt to occur between these two modes. On the one hand some *Primulæ* (notably *P. Boveana*) will occasionally have three of the lobes in the "contorted" fashion, and only two wholly covered; on the other, species of *Lysimachia*, such as *L. clethroides*, not rarely present flowers with one lobe wholly exterior and one wholly interior. By suppressing the tribe *Lysimachieæ*, *Cyclamen* and *Dodecatheon* are brought into juxtaposition, and the four tribes are made to rest on stable characters, — *Hottonieæ* on the anatropous ovules, *Corideæ* on the irregular flowers, and *Samoleæ* on the adnation of the base of calyx and ovary.

The authors of the Genera Plantarum have overlooked the heterogone dimorphism of the flowers of *Hottonia*.

Amsonia brevifolia. Glabra; foliis ovatis vel superioribus lanceolatis crassiusculis basi angustata subsessilibus; corollæ lobis ovatis oblongisve tubo subclavato dimidio brevioribus, fauce sub ore tantum barbato: stigmate subtrochleari apice bilobato; folliculis moniliformitorosis in articulis turgidis facile secedentibus. — S. Utah and W. Arizona, to the border of California. Mrs. Thompson, Dr. Parry, Dr. Palmer. There are four western species, forming a section, characterized by having a bilobed tip to the stigma, and the more or less clavate tube to the corolla always longer than the lobes; the calyx deeply parted into attenuate-subulate divisions (2 or 3 lines long); the stems lower, more branched, and bearing smaller or simpler flower-clusters than the eastern species. Of these the present and the nearly related *A. tomentosa*, Torr., have very torose follicles, disposed when dry to break up into joints. *A. longiflora*, Torr., and the following appear always to produce slender and continuous follicles, and have a tube to the corolla four or five times the length of the lobes.

Amsonia Palmeri. Glabra; foliis angusto-lanceolatis linearibusque sessilibus; corollæ albæ lobis ovatis (lin. 1½–2 longis) tubo clavato intus longe barbato 3–4-plo brevioribus; stigmate didymo hirtello; folliculis gracilibus continuis. — Arizona, Dr. Palmer. Described from specimens raised from seed collected by Dr. Palmer. Intermediate in appearance between *A. tomentosa*, which is sometimes glabrous, and *A. longiflora*. The stigma consists of two thick lobes, which are distinct almost down to the reflexed ring or collar. The eastern species, reducible to two, have a depressed-capitate stigma, truncate and entire at the apex.

Philibertia Torreyi. Velutino-pubescens; foliis cordato-lanceolatis vel sagittatis acuminatis; pedunculis folia æquantibus 10–15-floris; corollæ ut videtur albæ (lin. 8-9 diametro) lobis late ovatis obtusis extus puberulis villosissimo-ciliatis pedicello parum brevioribus; columna filamentorum vix ulla. — *Sarcostemma elegans?* Torr. Bot. Mex. Bound. 162, non Decaisne. — S. W. Texas, Parry, Bigelow. *P. elegans* is less pubescent, has smoother corolla variegated with purple within, narrower lobes, and a manifest column. *P. cynanchoides* (*Sarcostemma cynanchoides*, Decaisne in DC.) is a variable species, with smaller and more numerous flowers, on longer filiform pedicels, the smoothish corolla barely ciliate. *P. linearis* is a variable low species, of which *Sarcostemma heterophyllum*, Engelm., appears to be a form approaching the narrowest-leaved *P. cynanchoides;* and var. *hirtella* (*Sarcostemma*, Bot. Calif.), a narrow-leaved and pubescent form, the leaves rarely auriculate or cordate at base. *P. viminalis*

(*Asclepias viminalis*, Swartz) appears to be the most proper name for the *Sarcostemma Brownii* (not *Brownei*) of Meyer and Grisebach, *S. clausum* of Decaisne, mainly, and *S. crassifolium* of Chapman *P. undulata* (*Sarcostemma undulatum*, Torr. l. c.) is our only species with a conspicuous column, somewhat longer than the tumid scales of the stamineal corona.

ASCLEPIAS, &c. In elaborating this genus and its allies for the North American Flora, the limitation of the genera has to be considered. More than thirty years ago this work was done by the excellent Decaisne for De Candolle's Prodromus, evidently in a hurried way; Dr. Engelmann and the late Dr. Torrey have published important details; and the former has supplied me with full notes and many sketches of his elaborate studies, which, unfortunately, have for a long time remained unpublished. For his recent elaboration of the whole order in the new Genera Plantarum, Mr. Bentham could not critically examine all the species. Had he done so, he would probably have either re-established Nuttall's *Anantherix* (as Dr. Engelmann in his notes long ago proposed), or he would have remanded it to *Asclepias*. The process of the hood, specially characteristic of this last genus, although generally corniform, not very rarely takes the form of a pointless crest or plate, like that which in *Anantherix* divides at least the upper part of the cavity. Then *Acerates angustifolia* (*Polyotus*, Nutt.), as Nuttall intimated, has the technical character of *Asclepias* in a reduced form. I think I have found a character in the anthers, which may be turned to useful account; and it may be of no disadvantage that, while distinguishing *Acerates* from *Gomphocarpus* (the latter sufficiently heterogeneous without the addition of the former), it helps to separate Nuttall's original *Anantherix* (the anomalous *Asclepias connivens* of Baldwin) from the two more common species which Nuttall long afterwards added to it, along even with *Podostigma*, his *Stylandra*.

I venture to rearrange the genera in question, in the manner proposed in the foot-note.*

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* SYNOPSIS.

A. Cuculli coronæ basilares intus nudi, ab antheras longe remoti.

PODOSTIGMA, Ell. Corollæ lobi campanulato-erecti. Columna staminea prælonga. Antherarum alæ triangulares basi lata truncata.

B. Cuculli (aut basilares aut in columna brevi pl. m. elevati) antheris proximæ: corolla rotato-patens vel reflexa.

• Cuculli intus processu dorsali vel subbasilari corniformi seu cristæformi aucti.

To obviate confusion or mistake which may arise as to the priority of Elliott's names over those of Nuttall, it should be recorded that, al-

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ANANTHERIX, Nutt. (Gen.) Corolla sub anthesi reflexa. Columna sub cucullis brevissima. Cuculli adsurgentes, corollæ æquilongi, antheras longe superantes, oblongo-clavati apice incurvo, a latere compressi, præter marginem ventralem anguste apiceque dilatato-bilamellatum solidi, crista obtusissima inclusa. Antherarum alæ *membranaceæ*, deorsum valde dilatatæ, latissimæ, basi horizontaliter truncatæ. Caudiculæ capillares polliniis oblongis 2–3 plo longiores! Folia opposita.—A. CONNIVENS. *A. viridis*, Nutt. Gen. excl. syn. *Asclepias viridis*, Walt.

ASCLEPIODORA. Corolla rotato-patens. Cuculli basilares columnæ brevissimæ totæ inserti, patenti-adsurgentes, calceoliformes, prorsus cavi, versus apicem crista lamelliformi quasi bilocellati. Antherarum alæ corneæ basi pl. m. angustatæ. Caudiculæ polliniis pyriformibus breviores. Folia sæpius alterna.—A. VIRIDIS. *Asclepias viridis*, Walt. *Anantherix paniculatus*, Nutt. Trans. Am. Phil. Soc. v. 202. *Acerates paniculata*, Decaisne.—A. DECUMBENS. *Anantherix decumbens*, Nutt. l. c.

ASCLEPIAS, L. Corolla sub anthesi fere semper reflexa. Cuculli intus processu corniformi vel cristæformi aucti. Antherarum alæ corneæ deorsum usque ad basim truncatam seu late rotundatam dilatatæ. Folia sæpius opposita.

* * Cuculli intus prorsus inappendiculati: corolla sub anthesi reflexa.

ACERATES, Ell. Cuculli involuto-concavi, intus aperti. Antherarum alæ medio vel supra medium (nec basi) dilatatæ vel angulatæ. Folia sæpius alterna vel subalterna. Cæt. *Asclepiadis*.

SCHIZONOTUS. Cuculli saccati, ovales, intus toto longitudine columnæ adnati, extus longitudinaliter bivalves. Antheræ, etc., *Aceratis*. Folia opposita.—S. PURPURASCENS. *Gomphocarpus purpurascens*, Gray, Bot. Calif. i. 477.

GOMPHOCARPUS, R. Br. Cuculli intus vel apice aperti. Antheræ, etc., *Asclepiadis*.

ASCLEPIAS, L.

An American genus except for two African species, mainly North American. I do not see the way to a really natural arrangement of our species; but the following may serve as a key to them.

§ 1. Cuculli sessiles, nec basi attenuati: antherarum alæ basi latæ angulato-truncatæ vel auriculato-deflexæ, rarius rotundatæ.

* Corolla cum corona aurantiaca: folliculi nudi in pedicello decurvo arrecti: folia pleraque alterna vel sparsa: herba non lactescens!

A. TUBEROSA, L., et var. DECUMBENS.

* * Corolla læte rubra vel purpurea: folliculi nudi, in pedicello decurvo arrecti, *A. Curassavica* & *A. incarnata* exceptæ.

+— Cuculli aurantiaci: columna sat longa: herbæ glabræ.

A. CURASSAVICA, L. Naturalized if not native in Florida, &c.; now widely dispersed over the tropical coasts.

A. PAUPERCULA, Michx. *A. lanceolata*, Walt., a name which might be restored.

though the first volume of Elliott's work bears the date of 1821 upon the title-page, the first fasciculus was issued in the year 1816, and re-

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+- +- Cuculli purpurei vel purpurascentes: umbellæ multifloræ.

A. RUBRA, L., which is founded on Clayton's no. 263 in Gronov. Fl. Virg., with uppermost leaves accidentally alternate.

A. PURPURASCENS, L., founded on Dill. Elth. t. 28, and Herm. Parad. Bot. 33. *A. amœna*, L., founded on Dill. Elth. t. 27, not of herb. L., which is *A. variegata*.

A. INCARNATA, L., with var. PULCHRA, Pers., and var. LONGIFOLIA, the latter a Texan and New Mexican narrow-leaved form.

* * * Corolla et corona viridulæ, flavescentes, albæ, nunc sordide vel pallide purpurascentes.

+- Folliculi processibus mollibus echinati, crebre tomentosi, turgidi, in pedicellis deflexis arrecti: plantæ tomentosæ.

A. SPECIOSA, Torr. *A. Douglasii*, Hook.
A. CORNUTI, Decaisne. *A. Syriaca*, L.

+- +- Folliculi rostro tantum parce verrucoso-echinulato: herba glabra.

A. SULLIVANTII, Engelm.

+- +- +- Folliculi læves, aut glabri aut tomentulosi,

++ In pedicellis deflexis vel decurvis arrecti.

= Umbella in pedunculo elongato caulem simplicem terminante solitaria: folia arcte sessilia seu amplexicaulia: plantæ glaberrimæ glaucescentes.

A. OBTUSIFOLIA, L. *A. purpurascens*, Walt. Car. 103.
A. MEADII, Torr. in Gray, Man. ed. 2, addend.; ed. 5, 397.

= = Umbellæ in caule elato 2–4; pedunculis folia lata oblonga æquantibus vel superantibus: herba præter inflorescentiam glabra.

A. GLAUCESCENS, HBK. Specimens of this Mexican species were collected in S. W. Texas, and referred in the Botany of the Mexican Boundary Survey to *A. Sullivantii*.

= = = Umbellæ pedunculo caulibus abbreviatis foliisque orbicularibus longiore.

A. NUMMULARIA, Torr. Bot. Mex. Bound. 163, t. 45.

= = = = Umbellæ 2–3 vel plures, raro solitariæ; pedunculis (*A. cinerea* excepta) folia haud superantibus.

a. Folia lata seu latiuscula, sat magna: cuculli lati antheras vix parumve superantes: caules dodrantales ad 4-pedales.

1. Herbæ glabræ vel primum puberulæ, nunquam floccosæ.

A. CRYPTOCERAS, Watson, Bot. King. 283, t. 28. Sat humilis, decumbens, rotundifolia; cucullis saccato-ovatis apice bi-acuminatis cornu includentibus.

A. AMPLEXICAULIS, Michx. Decumbens; foliis carnosulis cordatis amplexantibus; cucullis obovato-truncatis, cornu fere incluso. — *A. humistrata*, Walt., "floribus rubris" exceptis.

issued, with the second fasciculus, before the close of that year; and the third and fourth appeared before November, 1817, — the latter

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A. Jamesii, Torr. Adscendens, subpedalis, primum farinoso-pubera; foliis orbiculatis seu late ovalibus crassis; cucullis latis apice truncatis, cornu cristæformi falcato parum exserto.

A. phytolaccoides, Pursh. Glabra, 4-5-pedalis; umbellæ laxæ pedicellis filiformibus elongatis; corolla viridula; cucullis albis vel subroseis eroso-truncatis angulis internis in dentem longe productis, cornu erecto tenui-subulato exserto. — *A. nivea*, Bot. Mag. t. 481, non L.

A. variegata, L. Glabra vel glabrata, 1-2-pedalis; umbellis compactis brevi-pedunculatis; corolla alba basi cucullisque ventricosis purpureo tinctis; cornu falcato-subulato brevi-exserto. — Founded wholly on syn. Dill. & Pluk. *A. nivea*, L. in part, as to syn. Gronov. & herb.

2. Tomentosa vel pubescens: umbellæ laterales brevi-pedunculatæ: flores viriduli: cuculli truncati: folliculi tomentosi vel canescens. Cismontanæ.

A. tomentosa, Ell. Cuculli in columna brevissima antheris breviores, processu vix exserto.

A. arenaria, Torr. Bot. Mex. Bound. 162. Cuculli antheras superantes, processu horizontaliter exserto.

3. Floccoso-lanuginosæ vel canescentes, demum nunc glabratæ; caules robusti: folliculi ovati. Ultramontanæ.

∘ Cuculli erecti apice horizontaliter truncati: herbæ pube brevi seu lana adpressa primum dealbatæ: umbellæ pedunculatæ, pedicellis lanuginosis.

A. Fremonti, Torr. Pacif. R. Rep. vi. 87, sine char. Canescenti-tomentosa vel pubera; foliis ovalibus vel oblongis obtusis retusisve nunc subcordatis petiolatis, margine lævi; corollæ albidæ lobis oblongo-ovatis; columna brevissima; cucullis antheris æquilongis marginibus antice in dentem productis, processu lato apice subulato inflexo parum exserto. — Northern California, Fremont, Newberry. Not since met with.

A. erosa, Torr. Bot. Mex. Bound. 162. *A. leucophylla*, Engelm. in Am. Nat. ix. 349; Gray, Bot. Calif. i. 476. — This species proves to have been first described by Dr. Torrey, on a glabrate state of the plant which, in the younger and white-lanuginous condition, appropriately received from Dr. Engelmann the name of *A. leucophylla*. Completely glabrate specimens have since come in. The rough erosion of the edges of the leaves, to which the original name refers, is evident in all the specimens.

∘ ∘ Cuculli ventricosi, processu lato incluso: herbæ lana longiore floccosa vestitæ. Californicæ.

A. eriocarpa, Benth. Umbellæ pedunculatæ.

A. vestita, Hook. & Arn. Umbellæ laterales sessiles.

b. Folia angusta, glabra; caules humiles ramosi: cuculli obtusi antheris breviores vel paullo longiores: folliculi ovati: umbellæ pauciflora.

A. brachystephana, Engelm. in Torr. Bot. Mex. Bound. 163. Cuculli brevissimi.

containing the genera in question. Nuttall's Genera of North American Plants appeared as a whole in the year 1818, the copyright bearing the date of April 3 of that year.

A. INVOLUCRATA, Engelm. l. c. Umbella foliis quasi involucrata.

c. Folia angustissima: caules humiles insigniter ramosi: cuculli lanceolato-subulati longissimi, basi concavi.

A. MACROTIS, Torr. Bot. Mex. Bound. 164, t. 45. A peculiar species.

d. Folia ovata seu oblonga, pubescentia vel glabella: caules erecti 1–2-pedales: cuculli oblongi, antheris 2–3-plo longiores, apice integerrimo rotundato.

1. Cuculli involuto-concavi, supra medium a processu corniformi apice incurvo vel inflexo exserto liberi: folliculi tomentosi vel pubescentes.

A. OVALIFOLIA, Decaisne in DC. *A. variegata* var., Hook. Fl. Bor.-Am. ii. 252, t. 141. *A. Nuttalliana*, Gray, Man. ed. 2, non Torr. — The habitat, "California," assigned to this species by Decaisne, stood in the way of its identification. The following, from a more south-westerly district, which I confounded with it, appears to be quite distinct.

A. HALLII. Puberula, mox glabrata: foliis crassiusculis ovato-seu oblongo-lanceolatis subacutis basi rotundatis brevi-petiolatis, costa valida, venis leviter adscendentibus rectis subtus prominulis: umbellis multifloris paucis corymbosis pedunculatis; corollæ viridulo-albæ purpurascentis lobis oblongis: cucullis elongato-oblongis integerrimis basi hastato-bigibbosis cornu sicæforme parum superantibus. — *A. ovalifolia*, Gray in Proc. Acad. Philad. 1863, 75. — Colorado; near Denver, E. Hall, no. 480. Upper Arkansas River, T. C. Porter. In aspect this most resembles *A. Sullivantii*. The follicles are not known; but the anther-wings are destitute of the corniculations at the basal angle which are conspicuous in the latter species.

A. OBOVATA, Ell. Sk. i. 321. A well-marked species, with somewhat the aspect of *Acerates viridiflora*. The anther-wings are manifestly bicorniculate at the salient basal angle. The hoods are dorsally somewhat hastately bigibbous above the short contracted base, and from the gibbosity are narrowly wing-appendaged upward and inward for some distance: the inner margins of the hood entire, straight, and so involute as to meet vertically for almost the whole length: at the very base inside is a pair of short and roundish fleshy internal auricles. The abruptly inflexed apex of the horn is subulate and traversed with a dorsal groove or channel.

2. Cuculli a latere complanati, solidi, margine ventrali petaloideo-bilamellato, lamellis semi-obovatis, parte dilatata cristam subconformem eroso-truncatam includente, angulo interno processu subulato breviter exserto apiculato.

A. NYCTAGINIFOLIA. Scabrido-puberula; caule ut videtur pedali adsurgente: foliis ovatis subrhombeis basi in petiolum sat longum contractis, venis adscendentibus: umbellis axillaribus 4–8-floris brevissime pedunculatis; pedicellis petiolo æquilongis; corolla viridula semipollicari, lobis oblongis; cucullis erectis antheris subtriplo longioribus: columna sub corona vix ulla: antherarum alis

Melinia angustifolia. Fere glabra, subvolubilis; caulibus filiformibus; foliis angustissime linearibus petiolatis; pedunculis brevibus

basi rotundatis. — Rock Spring, Providence Mountains, S. E. California, Palmer, 1876. — Belongs, with the preceding and the following, to the *Otaria* section of Kunth and Decaisne; but with a peculiar hood, not unlike that of *A. Coulteri* (infra) and certainly much like that of the original *Anantherix*. The crest is produced at its internal angle into the horn which is the distinguishing mark of *Asclepias*.

↔ ↔ Folliculi in pedicellis recurvis patulisve penduli vel patentes: caules elati junciformes, foliis subulato-filiformibus delapsis nudi: cucullis panduratis erectis antheras longius superantibus: processu cristæformi adnato intus brevissime cornuto.

A. subulata, Decaisne in DC. l. c.; Torr. in Pacif. R. Rep. v. 362, t. 7. — This remarkable *Asclepias* of the S. Californian and Arizonian desert appears to be the Mexican species briefly described by Decaisne; but a comparison of specimens should be made.

↔ ↔ ↔ Folliculi (tamquam noti) in pedicellis adscendentibus erecti, sæpius fusiformes.

= Folia lata plerumque quaterna: flores roseo-albi.

A. quadrifolia, L. A pretty species, with the middle leaves almost always in whorls of four.

= = Folia lata vel latiuscula opposita, nec verticillata: flores parvi albi.

A. perennis, Walt. *A. parviflora*, Ait., published one year later. *A. debilis*, Michx, partly confused with *A. quadrifolia*, to which the "Obs." relates. Towards its northern limits this species commonly wants the coma to the seeds. — Var. parvula is a low and remarkably small-leaved form of the species, from W. Texas, mentioned by Torrey in Bot. Mex. Bound. 164. — The two following related species are not known to occur within the United States; and the last by its narrow leaves would belong to the next division. They are introduced in reference to the synonymy.

A. nivea, L. (non herb., but the *Apocynum Persicariæ mitis*, etc., Dill. Elth. t. 29, and *A. Americanum*, etc., Plum. t. 80, on which the species was founded), Griseb. Fl. W. Ind. 419, excl. syn. Bot. Mag. (which belongs to *A. phytolaccoides*), is West Indian, and probably not in Louisiana, to which Grisebach credits it. It is distinguished from *A. perennis* by the greenish-white corolla, longer hoods with shorter horn, and an undulation near the base of the anther-wings, at least when dry.

A. virgata, Lagasca, Gen. & Spec. 14, is Mexican, and resembles the preceding in the flowers; but the petals are white, or sometimes rose-tinted (as in Brit. Fl. Gard. ser. 2, t. 85), the anther-wings plane, and the leaves linear or linear-lanceolate and less petioled. From Kunth's character (but not that of Decaisne) it may be the *A. linifolia*, HBK. I have seen only cultivated specimens, under the name of *A. angustifolia* and of *A. linearis*.

= = = Folia angusta seu angustissima (elongato-lanceolata ad lineari-filiformia), in sp. nonnullis verticillata, in unica alterna.

bibracteolatis plerumque unifloris nunc geminis; corolla campanulata fere 5-partita sepalis lanceolatis acuminatis parum longiore, lobis

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a. Corolla reflexa generis: cuculli cornu subulato exserto instructi.

1. Columna sub cucullis conspicua, antheris parum dimidio brevior.

A. MEXICANA, Cav. Ic. i. 42, t. 58. *A. fascicularis*, Decaisne in DC. *A. macrophylla*, Nutt. Pl. Gamb. 180. This species, which is common from Oregon to the borders of Mexico, appears to be identical with specimens collected in the valley of Mexico by Bourgeau (no. 63), and by Ghiesbreght still farther south. The figure in the Icones of Cavanilles very well represents it.

A. VERTICILLATA, L. A widely distributed species, including *A. galioides*, HBK., of Mexico. Var. PUMILA is a singularly dwarf or depauperate form, of the western dry plains, from Nebraska to New Mexico. Var. SUBVERTICILLATA (*A. verticillata* var. *galioides*, Torr. Bot. Mex. Bound. 164, chiefly), is a marked form, with single stems, simple or branched, the leaves mostly in pairs and threes, and their margins little revolute, the horns of the hoods rather less exserted. Decaisne's *A. verticillata* var. *linifolia* may include this; but it is evidently a mixture of *A. verticillata* (to which the specimens from "Florida and Georgia" may belong); of *A. virgata*, Lag. (*A angustifolia*, Roem. & Schult. &c.), which, from Kunth's character of opposite leaves and little exserted horn, may be *A. linifolia*, HBK.; and of *A. Mexicana*, Cav. (from which may come the character of leaves 4–6-nate), which must be identical with *A. fascicularis* of Decaisne. Here also *A. linearis*, Scheele in Linnæa, xxi.

(A. LINARIA, Cav, a Mexican species which has been associated with *A. verticillata*, differs much in the very short staminal column, short and almost included horns, and in the ovate follicles becoming erect on the decurved pedicel, which is not known to occur in any species of this section.)

2. Columna brevis crassior.

A. QUINQUEDENTATA. Facie fere *A. verticillatæ* var. *subverticillatæ*; foliis omnibus oppositis angusto-linearibus elongatis; umbellis paucifloris longiuscule pedunculatis; corollæ virescenti-albæ lobis ovalibus (lin. 2½–3 longis); cucullis antheris æquilongis columna triplo longioribus complicatis, dorso subcarinato, apice truncato grosse argute 5-dentato; processu falcato ad apicem cuculli usque adnato ibique bifido, lobo dorsali minimo dentiformi, ventrali in cornu subulatum inflexum breviter exsertum producto. — W. Texas, on or near the San Pedro River, C. Wright, no. 1689, referred in Torr. Bot. Mex. Bound. 164, to a variety of *A. verticillata*. It is much more related to the appended Mexican species.

(A. COULTERI. Præcedenti affinis; foliis oppositis filiformibus; umbellis 3–6-floris; pedicellis filiformibus pedunculo subæquilongis; corollæ albæ lobis oblongis (lin. 3–4 longis); cucullis columna crassa triplo longioribus antheras æquantibus complicato-compressis subquadratis dorso carinatis centro solidis apice truncatis subintegris; processu lato-subulato falcato infra apicem cuculli libero integerrimo longius exserto. — Mexico, Coulter, coll. no. 983. Single specimen, in flower: fruit not seen. The horn of the hood springs from a solid central portion, which is winged dorsally by a keel; the ventral part and top bilamellar and open.)

lanceolatis apice crassiusculo recurvo intus puberulis basim versus penicillato-barbulatis: coronæ phyllis spathulato-oblongis planis crassi-

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A. ANGUSTIFOLIA, Ell. Sk. i. 325, 1817. *A. tuberosa?* Walt. Car. fide Ell. *A. Michauxii*, Decaisne, l. c.: so named because a specimen in Michaux's herbarium is mixed with his *A. longifolia*; but Elliott's specific name has priority of all homonyms. The narrow and elongated thickish leaves are mainly alternate, which marks the species.

A. VIRIDULA, Chapm. Fl. 362. A well marked species, with opposite and very narrow leaves, most resembling the following; but with smaller yellowish-green flowers, and hoods considerably exceeding the anthers and the horn. — Found only in the vicinity of Apalachicola, Florida.

3. Columna sub cucullis nulla: folia opposita.

A. CINEREA, Walt. Well distinguished by the few-flowered lax umbels, and short very obliquely dorsally truncate hoods, the ventral cusps of which surpass the broad-triangular horn.

b. Corolla cum calyce rotato-patens, nunquam reflexa: crista mutica adnata in cucullo.

A. FEAYI, Chapman in litt. *A. cinereæ* subsimilis; foliis fere filiformibus longis patentissimis; umbellis terminalibus et subterminalibus brevi-pedunculatis paucifloris; corolla alba majuscula explanata; cucullis etiam albis præter costam petaloideis oblongis integris involuto-concavis antheris æquilongis sed patentibus intus dorso medio lamella semiovali integerrima instructis. — Tampa, Florida, Dr. Leavenworth (a single specimen in herb. Torr., collected 40 years ago), Dr. Wm. T. Feay, Dr. A. P. Garber. Dr. Chapman proposed to call this an *Acerates*, but in my view it is clearly an *Asclepias*.

§ 2. PODOSTEMMA. Cuculli stipitati, erecti, stipitibus antheras longe superantibus basibus columnæ adnatis, lamina spathulata intus cristata, crista inæqualiter bicorniculata: antherarum alæ medio latiores et subangulatæ.

A. LONGICORNU, Benth. *A. Lindheimeri*, Engelm. & Gray. — Ranges from Texas to Nicaragua. Follicles arrect on the deflexed pedicels.

§ 3. NOTHACERATES. Cuculli sessiles, oblongi, apice bidentati, intus crista angusta prorsus adnata e sinu corniculato-excurrente: antherarum alæ deorsum dilatatæ, supra basim late rotundatam auriculato-emarginatæ: pollinia arcuato-obovata. Habitus *Aceratis auriculatæ*.

A. STENOPHYLLA. *Polyotus angustifolius*, Nutt. in Trans. Amer. Phil. Soc. v. 201. *Acerates angustifolia*, Decaisne in DC. l. c. Nuttall noted the clear transition to *Asclepias*.

ACERATES, Ell.

* Gynostemium subglobosum: columna sub cucullis brevibus manifesta: folia pleraque alterna.

A. AURICULATA, Engelm. in Bot. Mex. Bound. 160. Foliis prælongis angustissimis umbellisque *Asclepiadi stenophyllæ* simillima; cucullis basi late auriculatis; antherarum alis angustis utrinque æquilatis.

usculis inappendiculatis basi corollæ et columnæ longiusculæ insertis corolla dimidio brevioribus; rostro stigmatis gracili integerrimo membranam antherarum erectam paullo superante. — *Metastelma? angustifolium*, Torr. Bot. Mex. Bound. 159. Ravine at Santa Cruz, Sonora, Mexico, very near the southern boundary of Arizona. Instead of constituting a new genus for this species, it is here referred to the extra-tropical South American genus *Melinia*, on account of the long and slender beak to the stigma, corolla-lobes distinctly but narrowly dextrorse-convolute, narrow sepals, &c. It is excluded from *Oxypetalum* by the absence of any tooth or appendage to the caudicles of the pollinia. The corona is attached rather more distinctly to the corolla than to the column, and the pieces are wholly distinct and rather widely separate; but a slight ridge at the base of each is decurrent into a slightly salient line on the column. The latter is about the length of the body of the anthers, which, again, bear a still longer erect membrane, ovate-oblong in form.

METASTELMA BLODGETTI. *Eumetastelma:* caulibus filiformibus; foliis parvis anguste lanceolatis; pedunculis 3–6-floris pedicillis (lineam longis) et petiolo brevioribus vel nullis; corollæ 5-partitæ lobis oblongo-lanceolatis intus sub apice penicillato-barbatis: coronæ

A. LONGIFOLIA, Ell. Columna paullo longiore; cucullis ovalibus integerrimis inappendiculatis marginibus ventralibus medio columnæ adnatis antheris dimidio brevioribus; antherarum alis semi-rhombeis basi magis attenuatis.

* * Gynostemium longius quam latum: cuculli oblongi parum breviores, basi bus columnam brevissimam tota longitudine obtegentibus: folia latiora sæpe opposita.

A. LANUGINOSA, Decaisne. Alæ antherarum paullo infra medium latiores subangulatæ.

A. VIRIDIFLORA, Ell. Alæ antherarum versus apicem latiores subangulatæ, basi longius angustatæ.

GOMPHOCARPUS, R. Br.

This genus is briefly defined as *Asclepias* without any crest or horn in the hoods. Except for two appended Californian species, which technically belong to it, it would be restricted to the Old World, mainly to Africa.

G. TOMENTOSUS, Gray, Bot. Calif. i. 477 (*Acerates tomentosa*, Torr.), has wholly the aspect and the structure of *Asclepias vestita*, of the same region, except as to the hoods, which are spreading or even depending, so that the *quasi*-bivalvular opening is superior or in appearance dorsal, giving a resemblance to the structure in the plant which I named *G. purpurascens*, but am now obliged to separate generically.

G. CORDIFOLIUS, Benth., except for the want of horn, would be an *Asclepias*, related to *A. phytolaccoides*.

squamis tenui-subulatis imæ basi corollæ insertis antheris cum columna breviore (sed manifesta) adæquantibus. — *M. parviflorum*, Chapm. Fl. 367, non R. Br. — Pine Key, S. Florida, Blodgett.

GONOLOBUS and LACHNOSTOMA. Later authors generally appear to have taken their idea of *Gonolobus* from those numerous tropical species which differ considerably from the typical ones of the Southern Atlantic States. The latter have not the colored-reticulated corolla of most of the tropical species, nor the broad and rounded lobes of many of them, nor the strongly salient-angled stigma, which has been made a part of the generic character, nor is the corona borne on the corolla, but either distinctly on the short stamineal column or at its very base at the junction with the corolla. *Lachnostoma*, HBK., was founded on a single and peculiar species, with "corolla subhypocrateriformis," or at least with tube as long as the limb, and with "corona pentaphylla, fauci corollæ inserta, foliolis cuneatis carnosis apice lunato-bilobis," etc. Noting that the column of filaments is adnate to the tube of the corolla (as it truly is for the whole length), Kunth, indeed, adds the query: "An igitur corona summo tubo filamentorum nec fauci corollæ inserta?" But the flowers I have examined, from Fendler's no. 1050, show that the first view was the correct one. On separating the tube of the corolla from that of the filaments, almost without lesion, the coronal appendages are left on the former, to which they manifestly belong. There are, moreover, vestiges of a stamineal corona, in the form of minute scale-like processes, one under the base of each anther. Decaisne adds three other species to the genus, and characterizes it by the "corona staminea gynostegio plus minusve adnata, pentaphylla." It will be allowed that, if the genus can stand upon the 5-phyllous corona, the mere insertion will be unimportant. But Mr. Bentham, enlarging the genus much more by adding Decaisne's *Ibatia* and *Chthamalia*, includes species with cup-shaped and with annular corona, thus resting *Lachnostoma* mainly on the insertion of this organ, which is variable from species to species, and really not different from that of typical species of *Gonolobus*. And our only reticulate-petaled species of the latter bears the annular corona distinctly on the column, close to its base, but wholly separate from the corolla. It thus appears, on the whole, that *Lachnostoma* should be restricted to the original *L. tigrinum*; and that *Chthamalia* (as the subjoined details show) should form only a subgenus of *Gonolobus*. Those reticulate-flowered tropical species (of which we have one, not very typical, representative in Texas), with all its variations in the gynostemium and corona, may form another section, which may

conveniently take the name of *Dictyolobus*, using here the Greek word in the sense of lobe, instead of pod.

The North American *Gonolobi*, of the Atlantic United States, are confused and difficult, partly because flower and fruit have seldom been had from the same plant. The subjoined conspectus gives the result of my study of the present available materials, aided by notes and sketches from Dr. Engelmann. *

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* GONOLOBUS, Michx. Fl. i. 119.

§ 1. DICTYOLOBUS. Corolla rete subtili conspicuo sæpius colorato venosissima, nunc rugulosa; lobis plerumque latis. Flores in nostra parvuli, in pleris majusculi.

G. RETICULATUS, Engelm. Mss. *G. granulatus*, Torr. Bot. Mex. Bound. 165, non Scheele in Linnæa.—Texas and adjacent borders of Mexico. Well described (except as to anther-tips, which really overlie the edges of the stigma), but wrongly referred, by Dr. Torrey. Scheele's description of the peduncles as shorter than the petiole, the pedicels as barely equalling the flowers, and the lobes of the corolla as lanceolate-attenuate from a broader base, is incompatible with the present species, and relates to a variety of *G. lævis*, Michx.

§ 2. EUGONOLOBUS. Corolla haud reticulata, lobis angustioribus: corona simplex, intus inappendiculata, columnæ basi sæpius inserta: stigmatis anguli parum prominuli: caules herbacei.

* Pedunculi pauci-pluriflori: corolla 5-partita, rotata, patentissima,

← Crassiuscula, viridula, extus cum calyce pedunculo brevi pedicellisque glabra: corona sub gynostemio pateriformis undulato-crenata, carnosa: antheræ membrana tenuiter scariosa super marginem stigmatis inflexa: folliculi læves 5-angulati.

G. SUBEROSUS, R. Br. *Cynanchum*, L. Hort. Cliff. 79 (excl. syn. *Apocynum scandens fruticosum fungoso cortice Brasilianum*, Herm. Parad. 53), & Spec. 212, excl. syn. Gronov. *Periploca Carolinensis*, etc., Dill. Elth. 300, t. 229, f. 296. *G. macrophyllus*, Chapm. Fl. 368. Corolla in alabastro late conica, lobis ovato-triangularibus a basi sensim angustioribus acuminatis supra albido-hirsutulis nunc glabratis.—Although Hermann's Brazilian plant, referred to, suggested the name, we may consider the Linnæan species as founded on the Dillenian plant, the figure of which very well represents what we take for this species. Moreover the Gronovian synonym belongs to *G. hirsutus* or *G. Carolinensis*. Decaisne's *G. suberosus*, with ovate pubescent sepals, and corolla glabrous within, must be some quite other species.

G. LÆVIS, Michx. Fl. i. 119. Minus pilosus vel glabellus; umbellis 5–10-floris petiolo vix æquilongis: foliis oblongo-cordatis; corolla in alabastro elongato-conica, lobis lanceolatis seu lineari-lanceolatis glabris; folliculis lævibus 5-angulatis.—Mississippi to Arkansas and Texas. Pursh introduces some confusion by adding a wrong synonym, and a consequent misstatement of the color of the corolla. It passes freely into

GILIA (DACTYLOPHYLLUM) PARRYÆ. Pygmæa, floribunda, pubescens; caule e radice annua nunc vix semipollicari floribus breviore nunc demum bipollicari a basi confertim ramoso; foliis plerisque oppositis 5–7-partitis, segmentis acerosis (lin. 2–3 longis); floribus in dichotomiis subsessilibus; calyce profunde 5-fido corolla fere triplo breviore lobis lanceolato-subulatis, tubo brevissimo obconico; corolla aut alba aut sulphurea aut cæruleo-lilacina, tubo brevissimo cum

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Var. MACROPHYLLUS. Foliis rotundato-cordatis majoribus (nunc 9–10-pollicaribus), acumine abrupto, lobis basilaribus rotundatis sinum sæpe claudentibus, pagina inferiore pube molli brevi nunc granulosa sæpius indutis; calycis lobis versus apicem rariter ciliolatis; folliculis brevibus angulatis 5-costatis. — *G. macrophyllus*, Michx. l. c. *G. viridiflorus*, Nutt. Gen. i. 163 (*G. Nuttallii*, Decaisne in DC.) *G. tiliæfolius*, Decaisne in DC. *G. granulatus*, Scheele in Linnæa, xxi. 759. *Vincetoxicum gonocarpos*, Walt. Car. 104, pro parte. — S. Carolina to Texas, Kentucky and Missouri. Elliott's *G. macrophyllus*, with muricate fruit and slender lobes to the corona, must be *G. Baldwinianus*, Chapman's is *G. suberosus*, and Decaisne's, in the Prodromus, is mainly *G. obliquus*. Pursh's addition of "flowers dark purple or dirty yellow" was taken from Walter, who evidently had more than one species under his *Vincetoxicum gonocarpos*.

+ + Corolla submembranacea, purpurea, ochroleuca, vel albida: corona cupuliformis, gynostemio adæquans: membrana antherarum inconspicua vel obsoleta: pedunculi sæpius longiusculi pluriflori, cum calyce pedicellisque pubescentes: corolla extus pl. m. pubera: folliculi teretes muricati.

++ Coronæ subcarnosæ margo tantum crenatus.

G. OBLIQUUS, R. Br. Corolla intus sanguineo-purpurea, extus viridula, lobis lineari-ligulatis: corona 10-crenulata, crenulis alternis angustioribus plerumque emarginatis vel bidenticulatis. — Roem. & Schult. Syst. vi. 64; Bart. Fl. Am. Sept. iii. t. 99; Gray, Man. ed. 5, 399. *G. hirsutus*, Nutt. Gen. i. 163, non Michx. *G. macrophyllus*, Decaisne, l. c., non Michx. *Gonolobium hirsutum*, Pursh, Fl. i. 179. *Cynanchum obliquum*, Jacq. Ic. Rar. t. 341. *C. discolor*, Sims, Bot. Mag. t. 1273. *C. hirtum*, L.? quoad *Apocynum scandens Virginianum*, etc., Moris. Hist. The most northern species, ranging from (Carolina?) the mountains of Virginia to Pennsylvania, Ohio, and Kentucky. — Var. SHORTII, apparently a form with larger (and dull purplish?) flowers, said to exhale the scent of *Calycanthus*-blossoms: known only in specimens collected by Short and Peter, near Lexington, Kentucky, where it should be re-discovered.

G. HIRSUTUS, Michx. l. c. Pedunculi pauciflori: corolla intus atro-purpurea, lobis elliptico-oblongis: corona margine obtuse æqualiter 10-crenata. — Virginia and Tennessee to Florida. The corolla in dried specimens by transmitted light shows a reticulate venation more distinctly than any other species of this group.

++ ++ Corona 5-lobata, dentibus geminatis vel bifidis interjectis: pedunculi pluriflori sublongiores.

G. CAROLINENSIS, R. Br. Corolla badia vel atro-purpurea, majuscula, lobis oblongis seu lineari-oblongis: corona subcarnosa, undulato-5 lobata, sinubus processu subulato bifido gynostemio adæquante instructis. —*Cynanchum Caroli-*

fauce obconico lobis obovatis integerrimis vel erosulis apice sæpius cuspidatis 2–4-plo breviore; antheris oblongis; capsula ovali-oblonga polysperma; seminibus angulatis fere cubicis, tegumento externo laxo tenui nec spirillifero nec mucilaginoso. — San Bernardino Co., S. E. California, on desert plains near the head of the Mohave River, Parry and Lemmon, also Palmer. A very distinct and pretty little species, in appearance somewhat intermediate between *G. dianthoides* and a

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nense, Jacq. Ic. Rar. t. 342. This from the character should be Walter's *Vincetoxicum acanthocarpos*, Elliott's *G. Carolinensis* (excluding the fruit), and probably *G. hirsutus*, Sweet, Brit. Fl. Gard. t. 1. It extends from South Carolina to Louisiana and Arkansas.

G. Baldwinianus, Sweet. Corolla albida vel flavida, lobis oblongis demum subspathulatis tenuioribus: corona fere membranacea altius fissa, segmentis 5 latis sæpius emarginatis, 10 per paria interjectis lineari-subulatis duplo longioribus stigma superantibus. — *G. macrophyllus*, Ell., non Michx. *G. Carolinensis*, Nutt. Gen. i. 163, non R. Br. *G. hirsutus*, Lodd. Cab. t. 365? Georgia and Alabama to N. W. Arkansas. Elliott and Nuttall, who describe from dried specimens, speak of the corolla as "obscure yellow" or "yellowish," but Engelmann, who collected it in Arkansas, says "whitish"; and Buckley on the ticket of his specimens in the Torrey herbarium, collected in Alabama, writes "flowers white." This species clearly connects *Polystemma*, Decaisne, with *Eugonolobus*.

* * Flores solitarii subsessiles: antheræ etiam *Chthamaliæ*, sed corona simplex *Eugonolobi*.

G. sagittifolius. Humilis, volubilis, vix puberula; foliis subcarnosis parvis sagittatis, auriculis obtusis: corolla lutea glabra alte 5-fida, lobis lanceolato-linearibus: corona imæ basi corollæ inserta cyathiformia integerrima; folliculis lanceolatis lævibus. — Rio Limpio, W. Texas, Wright. This is Dr. Torrey's *G. parvifolius* only as respects the specimen of Wright referred to by him, and from which he described the follicle.

§ 3. Chthamalia. (*Chthamalia* & *Lachnostomatis* spec. Decaisne.) Corolla haud reticulata, campanulata vel rotata, 5-loba vel 5-partita: corona intus cristata vel appendiculata, raro (appendicibus liberis) duplex: antheræ prominulæ a stigmate magis liberæ, marginibus nunc (*Asclepiadis* modo) alis corneis instructæ. Plantæ humiliores sæpius parviflores.

* Diffusæ, nec volubiles: pedunculi nulli: pedicelli 2–3 ad axillas fasciculati: folia cordata.

G. pubiflorus, Engelm. Pl. Lindh. i. 44; Torr. Mex. Bound. 165. *G. prostratus*, Baldw. in Ell., non R. Br. *Chthamalia pubiflora*, Decaisne. — The only species of this section east of the Mississippi, and an ambiguous one. It has exactly the aspect of the two following, except that the campanulate corolla is cleft barely to the middle (in which it is very unlike true *Gonolobi*), but the cup-shaped crown, which overtops the stigma, is almost simple within, the five crests being attenuated and inconspicuous or even obsolete: there are five minute adnate auricles at the very base. The follicle, which I have not seen, is said to be smooth.

very dwarf *G. dichotoma*, desirable for cultivation on account of its abundant and variously colored flowers of comparatively large size for the pygmy growth, the corolla being fully half an inch long, indeed longer than the earlier stems. At the suggestion of Mr. Lemmon, this dainty plant is dedicated to Mrs. Dr. Parry, one of the botanical party who passed the last winter and spring in the San Bernardino district — making many interesting discoveries — and whose services to botany well merit this recognition.

G. BIFLORUS, Nutt. in herb. DC.; Torr. l. c. *Chthamalia biflora*, Decaisne. In this the corolla is rotate and deeply 5 cleft; the corona deeply lobed; and the canaliculate crest adnate to each lobe is connected at base with the column, while it terminates above in the stout and conspicuous thickened acumination which incurves over the edge of the stigma. The follicles, as in the next, are large and muricate. — Var. WRIGHTII, also from Eastern Texas, is a form with the corolla almost 5-parted into narrower lobes, and the cusps of the corona shorter.

G. CYNANCHOIDES, Engelm. Pl. Lindh. i. 43. has the inflorescence much inclined to be racemose-clustered on a peduncle-like summit of the stem, the upper leaves being reduced and bract-like, the corolla rotate-campanulate and almost 5 parted, and the very obtusely 5 lobed corona is appendaged within by a shorter crest which terminates in a free and blunt apex, shorter than the lobe to which it adheres.

* * Caules humiles sed volubiles: flores (luteoli) subsessiles solitarii, raro gemini: folia parva, pl. m. hastata.

G. PARVIFOLIUS, Torr. l. c., excl. fruct. The corolla is globose in the bud, deeply 5-lobed, and almost rotate when expanded, the lobes ovate. The fleshy corona is at the very base of the short column; its lobes ovate, spreading, appendaged with a very broad adnate crest, the edge of which at base is united with the column, at the apex extended into a minute inflexed tooth.

G. HASTULATUS. *Lachnostoma hastulatum*, Gray, Bot. Calif. i. 620. In this the corolla is narrowly oblong in the bud, the lobes linear. The corona is of distinct pieces, like the hoods of *Asclepias*, and, as in that genus, borne at the summit of the column, close under the anthers; the ligule or horn within is prominently exserted and inflexed. Follicle rather slender and minutely muricate.

* * * Caules elongati subvolubiles: pedunculi axillares folio sagittato-cordato breviores, umbellato 3–5-flori: corolla oblongo-campanulata, lurida, majuscula (½ pollicaris), alte 5-fida, lobis lineari-oblongis: corona cyathiformis, sub-lobata, intus lamellis 5 columnæ adnatis quasi septata.

G. PRODUCTUS, Torr. l. c. The follicles are ovate and smooth. The species ranges from Western Texas to Arizona, and into adjacent parts of Mexico.

* * * * Pedunculi filiformes folia mox longe superantes, quasi racemoso-pauciflori: flores perpusilli: corolla rotata: corona alte laciniata, duplex: caulis humilis, a basi ramosissimus, nec volubilis.

GILIA (LEPTOSIPHON) BREVICULA. Inter *Tenuifloras* notabilis tubo corollæ (cæruleæ seu violaceæ) limbo parum sesquilongiore, foliis brevibus calyceque subglanduloso-hirtellis. — On the Mohave River, S. E. California, Dr. E. Palmer, 1876. — Stem barely a span high, more branching than in *G. androsacea*, which it much resembles; the branches becoming cymose. Leaves only 3 lines long; the divisions acerose-subulate, the pubescence short-hirsute and glandular. Tube of the corolla barely 5 lines long, nearly double the length of the calyx and bracts; the oval lobes fully 3 lines long. Stamens exserted from the very short cyathiform throat. Style exserted: stigmas long and slender, almost capillary, fully equalling the lobes of the corolla. The latter appears to have been blue, or violet-purple. The flowers are abundant, and the species would be attractive in cultivation.

GILIA (IPOMOPSIS) HAYDENI. *G. subnudæ* affinis, ramosior, fere glabra; ramulis pedunculis (corymbosis longioribus) calycibusque

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G. PARVIFLORUS. *Lachnostoma? parviflorum*, Torr. l. c. This remarkable species closes the series. Its principal corona is somewhat like that of *G. Baldwinianus*, which is a genuine *Gonolobus*. It is divided into five short and broad membranaceous lobes, which from the apex are produced into a pair of slender subulate processes, with a wide sinus between: opposite each lobe within, and separately inserted, is a similar and longer process, which may answer to the ligule or other internal appendage of the foregoing species, become wholly free. The follicle is ovate and tuberculate-muricate.

(G. PROSTRATUS, R. Br., the *Lachnostoma prostratum* of Decaisne, is also a *Chthamalia*, with lobes of the corona nearly distinct, each produced into a pair of processes like those of the preceding, but also with a shorter intermediate one, and still another before this, the latter answering to the internal ligule adnate up to the notch of the lobe.)

To *Ptycanthera* — a little known genus, well referred by Bentham (who had not seen specimens) to the *Gonolobeæ*, and marked by the direct adhesion of the corona-lobes by the whole length of the middle of the inner face to the column — there are two Cuban species to add, both with flat-topped stigma: viz.,—

PTYCANTHERA ACUMINATA = *Orthosia acuminata*, Griseb. Cat. Pl. Cubens. 175. In this the lobes of the deeply 5-parted corona are ovate-oblong, attached along the middle only to the whole length of the column, the sinuses rounded and open. Pollinia obliquely short-pyriform, pellucid at the insertion of the caudicle.

PTYCANTHERA OBLONGATA = *Orthosia oblongata*, Griseb. l. c. Lobes of the disk oblately oval and emarginate, with thinner free edges, the centre adnate to the whole length of the column, which is considerably shorter than in the preceding species, the sinuses somewhat auriculate. Pollinia nearly oblong, strongly arcuate.

præsertim glandulosis; foliis radicalibus pinnatifidis, caulinis parcis brevibus linearibus integerrimis; corolla tubuloso-infundibuliformi gracili (½–¾-pollicari) læte rosea, tubo lobis obovatis 3–4-plo longiore; antheris subsessilibus fauci insertis; stigmatibus brevissimis; ovarii loculis 6-ovulatis 2–3-spermis; seminibus oblongis, testa tenui sub aqua nec spirillifera nec mucilaginosa. — High plains of the San Juan, S. W. Colorado or adjacent part of Utah, Brandegee, in Hayden's Exped. 1875.

GILIA (IPOMOPSIS?) CÆSPITOSA. Glanduloso-puberula, viscida; caulibus brevissimis e caudice multicipite cæspitante pedunculis ramisve floridis nudiusculis (2–3-pollicaribus) laxe 3–5-floris terminatis; foliis radicalibus confertis crassiusculis spathulatis vel spathulato-lanceolatis (imis lin. 2–3 longis) obtusissimis, sequentibus longioribus mucronatis, pedunculorum ad bracteas subulatas diminutis; pedicellis fere nudis; calycis angusti lobis subulato-setaceis; ovulis in loculis paucis. — Rabbit Valley, Utah, on barren cliffs of sandstone, at 7,000 feet, L. F. Ward, in Powell's Expedition, 1875. The corollas gone, and fruit not formed; but the plant cannot belong to any already published species.

PHACELIA (EUTOCA) GRISEA. Annua, cinereo-pubescens et hirsuta, viscidula: caule ultra-spithamæo a basi ramoso; ramis patentibus sat validis, hirsutia patentissima rigidula, pube brevissima densa; foliis ovatis oblongisque integerrimis (semipollicaribus ad pollicaria) brevi-petiolatis cinereo-strigosis; spicis elongatis densifloris; calycibus subsessilibus, sepalis spathulatis patenti-hispidis corolla (alba?) subdimidio brevioribus capsulam ovatam acutam paullo superantibus; filamentis longe exsertis pilis brevibus papillisve retrorsis hirsutulis basi plicis transversis adnatis appendiculatis; ovulis 10–12; seminibus 5–6 grosse rugoso-favosis. — On Pine Mountain, back of San Simeon Bay, California, Palmer.

ERITRICHIUM SETOSISSIMUM. *Krynitzkya* inter subsect. *Pseudo-myosotidem* et *Pterygium*, habitu potius *E. glomerati*, cinereo-pubescens, hirsutulum, et setis urentibus hispidissimum; caule valido ultra-bipedali e radice ut videtur bienni; foliis spathulatis seu lanceolatis; spicis racemoso-paniculatis pauci- et parvi-bracteatis, fructiferis elongatis strictis (4-pollicaribus); corolla alba parva (lin. 2–3 longa), tubo lobis rotundatis vix duplo longiore intus versus basin 10-dentato-annulato, fauce insigniter 5-fornicata; antheris brevi-oblongis; nuculis pro genere magnis ala integerrima circumdatis (cum ala ovata lin. 2–3 longis) opacis scabriusculis, facie dorsali parum convexis, ventrali angulo obtusissimo per sulcum angustissimum gynobasi subuliformi æquilongæ

affixa. — Shores of Fish Lake, Utah, at 8,700 feet, L. F. Ward, in Powell's Expedition, 1875. A most remarkable species, which, without the fruit, might be confounded with *E. glomeratum*.

ERITRICHIUM HOLOPTERUM. *Krynitzkia*, facie *E. leiocarpi* et *E. muriculati* formæ validioris; corolla fauce fornicibus conspicuis basi tubi appendicibus parvulis instructis: nuculis omnibus ala angusta integerrima circumdatis dorso muricatis. — S. Utah, Capt. F. M. Bishop; Ehrenberg, Arizona, Palmer.

PECTOCARYA (GRUVELIA) PUSILLA. — *Gruvelia pusilla*, A. DC. Prodr. x. 118. That most successful plant-finder, Rev. E. L. Greene, sends this Chilian species from the vicinity of Yreka, in the northern part of California, east of the Coast Range mountains, therefore far from the coast. It there abounds in company with the natives of the region, and, as Mr. Greene states, would not be suspected to be other than indigenous.

PECTOCARYA (GRUVELIA) SETOSA. A præcedente distinctissima foliis etc. hispidis; calyce setis paucis validis divaricatis horrido; nuculis majoribus ala latiuscula nunc undulata marginatis undique uncinato-setulosis. — S. E. California, on the desert plains of the upper Mohave River, Palmer.

LYCIUM GRACILIPES. Viscidulo-puberulum; foliis crassiusculis spathulatis seu oblongo-obovatis (lin. 2–6 longis): pedicellis pubero-glandulosis folia floralia longius superantibus flori subæquilongis: calyce campanulato breviter 5-dentato; corolla infundibuliformi "violacea nunc albescente" semipollicari, tubo proprio calycem vix superante, fauce sensim ampliata, lobis 5 lato-ovatis obtusissimis lineam longis; filamentis filiformibus fauci versus basim insertis inferne villosulis; antheris subinclusis. — Northern Arizona, at Williams Fork (alias Bill Williams' River), Palmer, 1876.

ANTIRRHINUM (PSEUDORONTIUM *) CHYTROSPERMUM. Calycis segmentis oblongo-lanceolatis tubo corollæ æquilongis; cyatho seminis maximo ollæformi. — Ehrenberg, Arizona, Palmer.

PENTSTEMON COMARRHENUS. *Speciosi*: gracilis, glaucescens, glaber vel foliis (summis linearibus, imis oblongis ovalibusque) minutissime

* ANTIRRHINUM sect. PSEUDORONTIUM. Capsula tenui-chartacea subdidyma, loculis æqualibus apice irregulariter rumpentibus *Asarinæ*. Semina ala pelviformi modo *Orontii*. — Spec. 2, Am. Bor.-Occ. Merid.; foliis alternis petiolatis ovatis integerrimis; caule erecto; pube viscidula; floribus parvis. A. CYATHIFERUM, Benth., ex tab. & descr. calycis segmentis lineari-lanceolatis tubo corollæ multo brevioribus, cyatho seminis majusculo; & A. CHYTROSPERMUM supra.

pruinoso-puberulis; panicula virgata laxa; pedunculis pedicellisque longiusculis; sepalis ovalibus parvis (haud ultra lin. 2 longis); corolla (pollicari) cæruleo-purpurea, tubo inferne longius attenuato; antheris longissime lanatis. — Common in Utah, especially southward, coll. by Gordon, E. W. Emerson, Mrs. Thompson, Siler, and recently by L. F. Ward. Like *P. secundiflorus*; but flowers larger, looser and hardly secund in the panicle; and the anthers long-woolly almost in the manner of *P. Menziesii*. Still nearer, perhaps, to the less-known *P. strictus*, Benth.; but that has much smaller and narrower flowers in a crowded inflorescence, acuminate sepals, &c.

PENTSTEMON WARDI. *Speciosi*: crebre cæsio-puberulus; caule subpedali; corollis extus pallidis; antheræ glabræ loculis subcartilagineis basi acutis apicibus contiguis longiuscule inapertis: cæt. *P. glabri*. — Utah, near Glenwood, at 5,300 feet, L. F. Ward, in Powell's Expedition, 1874.

MIMULUS PALMERI. *Eumimulus*: viscidulus sed fere glaber, spithamæus e radice annua, paniculato-ramosus; foliis sessilibus integerrimis, imis spathulato-oblongis, superioribus linearibus; pedunculis filiformibus folium bis superantibus: calyce haud obliquo, dentibus æqualibus latis obtusissimis; corolla (¾ poll. longa) more *Eunani* infundibuliformi sanguineo-purpurea calyce triplo longiore, lobis brevibus subæqualibus. — S. E. California, on the Mohave River, Palmer. A truly handsome species, well worthy of cultivation.

ORTHOCARPUS LASIORHYNCHUS. *O. lucero* proximus; pube molliore; floribus majoribus; corollæ læte aureæ saccis amplioribus galea tenuiter subulata dense albo-villosa superatis. — Mohave River, S. E. California, Palmer, 1876.

MONARDELLA PALMERI. Nana, rhizomatibus stoloniformibus perennans; capitulis corollisque *M. odoratissimæ*; caulibus vix spithamæis parum puberulis; foliis confertis oblongo-linearibus lanceolatisve obtusissimis parvulis crassiusculis viridibus fere glabris, venis glandulisque punctiformibus obsoletis; bracteis rubescentibus oblongis subhirsutis ciliatis; dentibus calycis lanceolatis acutis intus marginibusque parce hispidis. — Redwood forests on Sta. Lucia Mountains, California, Palmer.

STACHYS ROTHROCKII. Spithamæa, a basi ramosa, villoso-lanata; radice ut videtur perenni; foliis omnibus sessilibus lanceolatis obtusiusculis subintegerrimis (pollicaribus), floralibus superioribus flores haud superantibus; verticillastris sæpius trifloris spicato-confertis; calyce sessili subcampanulato, dentibus subovatis muticis; corollæ (lin. 4–5 longæ) tubo incluso, galea saltem extus albo-villosa. — Zuni Village,

New Mexico, Dr. J. T. Rothrock, in Wheeler's Expedition, 1874. In aspect considerably unlike any other North American species: apparently indigenous.

ERIOGONUM GREENEI. *Heterosepala* inter *E. proliferum* et *E. ovalifolium*: majusculum; foliis oblongis acutiusculis; scapo ultra-spithamæo sub involucro primario sessili 3-radiato, radiis elongatis involucra 1–3 turbinata (lin. 3 longa) gerentibus quandoque proliferis; perigonio albo (lin. 3 longo), segmentis exterioribus ovalibus basi cordulatis per costam viridulam interioribus angustioribus haud emarginatis longius adnatis. — Northern California, on rocky hills about Yreka, E. L. Greene. An interesting accession to the *Heterosepala* section.

OXYTHECA TRILOBATA. Cymoso-ramosa; foliis radicalibus bracteisque fere *O. Watsoni*; involucris longius pedunculatis pro genere maximis alte 5-partitis nunc hinc divisis, phyllis patentibus foliaceis oblongo-lanceolatis costa valida excurrente aristatis; perigonii sepalis ligulato-oblongis superne trifidis, lobis ovato-lanceolatis erosulis acuminatis. — San Bernardino Co, S. E. California, Lemmon and Parry.

CHLORÆA AUSTINÆ. Planta alba aphylla; radicibus carnoso-fibrosis; caulibus fasciculatis (subpedalibus) laxe vaginatis; spica oblonga laxiuscula; floribus pro genere parvis albidis (perianthio parum semipollicari); labello trilobo, lobo medio integerrimo transverse oblongo; anthera modo *Cephalantheræ* substipitata. — Banks of a wooded ravine in the Sierra Nevada, California, near Quincy, in Plumas Co., Mrs. R. M. Austin; — whose zeal and services to botany, and notably her observations upon the habits of *Darlingtonia*, render it particularly proper that this remarkable plant of her own discovery should commemorate her name. I refer it to the South American genus *Chloræa*, rather than to the European and North Asian *Cephalanthera*, on account of its habit, and because there is no articulation between epichilium and hypochilium.

POSTSCRIPT.

SAXIFRAGA CHRYSANTHA. *S. Hirculo* et *serpyllifoliæ* affinis: caudiculis perennantibus cæspitosis diapensioideo-foliatis cum stolonibus filiformibus; foliis spathulatis seu lineari-spathulatis obtusissimis nitidulis glabris (lin. 2–3 longis) basi sensim angustatis sessilibus, caudiculorum crebre rosulato-imbricatis; caulibus floriferis scapiformibus fere bipollicaribus 1–4-foliatis 1–2-floris glabris vel superne cum

calyce reflexo glanduloso-hirsutulis; petalis ovalibus læte aureis basi ecallosis supra unguem truncatis vel subcordatis; ovario et capsula late ovatis apice breviter bilobis; seminibus oblongis striolatis nitidis. — *S. Hirculus*, Gray in Am. Jour. Sci. xxxiii. 409 (coll. Parry, no. 164 & 166), non L. *S. serpyllifolia*, Gray in Proc. Acad. Philad. 1863, 62 (coll. Hall & Harbour, no. 199), non Pursh. High alpine region of the Colorado Rocky Mountains, especially abundant on Torrey's and Gray's Peaks, at 11–14,000 feet, its golden flowers close to the sward, more brilliant than those of the equally abundant *Geum Rossii* which accompanies it. *S. Hirculus* occurs at very much less elevation, fully resembling the Arctic American and the European plant. *S. serpyllifolia*, Pursh, now better known by good Alaskan specimens, collected by Prof. Harrington in 1871–2, is more slender, the flowers solitary and smaller, the calyx not reflexed even in fruit, petals light yellow, cells of the anther parallel, ovary partly immersed in a disk, its base adnate to the base of the calyx, the capsule distinctly 2-horned at the summit, and the tip of the horns narrow and styliform. These distinctions were made out several years ago, and the Rocky Mountain species has been freely distributed among botanists under the name of *S. chrysantha*, but it has accidentally escaped publication.

VI.

CONTRIBUTION FROM THE LABORATORY OF S. P. SHARPLES.

SCHWEINFURT GREEN:

SOME EXPERIMENTS ON THE ACTION OF ARSENIC TRIOXIDE ON COPPER ACETATE, WITH THE VIEW OF INVESTIGATING THE COMPOSITION OF THE ABOVE COMPOUND.

By E. R. Hills.

Read by title, November 8, 1876.

After the completion of the paper on Scheele's Green by Professor S. P. Sharples, I became interested to know something about the composition of the closely allied substance, Schweinfurt green, — as to whether it was perfectly definite in its composition, or whether it varied in a similar manner to Scheele's green. I therefore obtained a sample of Schweinfurt green from the Massachusetts Institute of Technology, which was procured by them in the market for analysis.

This was submitted to a careful analysis, and gave as follows : —

Analysis No. I.

	Per cents.
Copper oxide,	25.82
Arsenic trioxide,	45.18
Acetic anhydride ($C_4H_6O_3$),	15.40
Sulphuric anhydride (SO_3)	1.76
Barium sulphate,	11.44
	99.60

If now we deduct from this the sulphuric anhydride and barium sulphate, and calculate the percentages anew, we have, —

	Per cents.	Atomic Ratios.
Copper oxide,	29.88	4.26
Arsenic trioxide,	52.30	3.00
Acetic anhydride,	17.82	1.98
	100.	

A sample of Schweinfurt green was then obtained from Messrs. Folsom & Co. of this city. This sample was said to be perfectly pure, and was made in their works. It was of a much brighter shade than the preceding, and gave on analysis: —

ANALYSIS No. II.

	Per cents.	Atomic Ratios.
Copper oxide,	30.97	4.43
Arsenic trioxide,	52.82	3.00
Acetic anhydride,	16.03	1.79
	99.82	

This is very nearly the same as the preceding sample, calculated as pure *copper aceto-arsenite*. It corresponds quite nearly to the formula,

$$2\ (CuOC_4H_6O_3)\ 3\ (CuOAs_2O_3),$$

which calculated to percentages is thus: —

	Per cents.	Atomic Ratios.
Copper oxide,	33.19	5.
Arsenic trioxide,	49.73	3
Acetic anhydride,	17.08	2.
	100.	

It will be seen by comparing the percentages that both samples analyzed contain more arsenious acid than is called for by the formula: this is most probably due to the difficulty of washing out the excess of arsenic in process of manufacture.

The formula given in the books for Schweinfurt green is, —

$$CuOC_4H_6O_3\ 3(CuOAs_2O_3),$$

which was based upon the following analysis: —

	Per cents.	Atomic Ratios.
Copper oxide,	31.24	3.96
Arsenic trioxide,	58.62	3.00
Acetic anhydride,	10.13	1.00
	100.	

This analysis was made by E. Ehrmann in the laboratory of Professor Von Liebig, and the results were published in "Der Annalen der Pharmacie," * in 1834, in which paper Ehrmann, after giving the

* Der Annalen der Pharmacie, Band XII., 1834, Seite 72.

origin of the salt, gives a formula for its preparation, and then the composition as determined by him.

The receipt he gives is as follows, which he states works as well in small amounts as in large : —

"10 parts verdigris are mixed with as much water at 50–55° as is necessary to produce a moderately thin emulsion: this is then passed through a fine hair sieve, to separate the marc of the grape or the small particles of copper from the basic acetate of copper.

"This emulsion is poured still warm into a solution of 8 parts of powdered arsenious acid in 100 parts water, which is kept in a state of brisk ebullition in a copper kettle. The mixing is done quickly, and meanwhile the fire must be kept bright and hot, so that the boiling of the solution of arsenious acid may not be interrupted. The color appears in a few minutes. If the verdigris is added cold, or the boiling of the arsenious acid is interrupted, the precipitate is of a dull yellow-green color, in which case some acetic acid must be added to the solution, boiling a few minutes longer, and allowed to stand to cool by itself, after which the dull precipitate becomes crystalline, and is converted into Schweinfurt green.

"On account of the difficulty with which the arsenious acid dissolves in pure water, many makers add to the water, with the 8 parts of arsenious acid, $\frac{1}{16}$ parts (that is, to 8 pounds 1 oz.) of pure potash; but, before the addition of the verdigris, the solution must be made neutral with acetic acid. . . .

"If a boiling solution of neutral acetate of copper and one of arsenious acid in water, the amounts of each being equal, are mixed, a very voluminous precipitate of a dull olive-green color occurs immediately: if the supernatant liquid be allowed to stand in contact with this some hours, or cool slowly with it, it loses its gelatinous condition, sinks together, becomes crystalline in granular crystals, and assumes the useful color of Vienna green.

"The compound acquires a still more brilliant color, if an equal volume of cold water is added to the liquid after mixing.

"If the mixture, instead of standing by itself, be boiled a few minutes, the conversion to the crystalline salt is accomplished in a very short space of time.

"The difference in the shades of color is due mainly to the size of the crystalline grains: when rubbed to a fine powder on a color-slab, their appearance is similar. . . .

"The pure compound which was obtained by the preceding method was submitted to analytical investigation. . . .

"Schweinfurt green is a double salt of acetic acid, arsenious acid, and oxide of copper: it is entirely insoluble in water. All mineral acids, and even concentrated acetic acid, extract the oxide of copper from it, leaving the white arsenious acid behind. It is also decomposed by fixed alkalies, except that in this case oxide of copper remains behind. If the alkaline liquid, which has dissolved the arsenious acid, is boiled with the precipitated oxide of copper, this is reduced to the suboxide by the arsenious acid: the oxide, which is at first black, becomes orange-red by boiling. . . . Ammonia dissolves it without decomposition, with the well known blue color of copper."

Some Schweinfurt green was now prepared by the first of these receipts.

Experiment No. 1.

Took 20 grams verdigris and made it into a thin paste with water, rubbing it well in a mortar to break up any lumps and mix thoroughly. 16 grams of arsenic trioxide were dissolved in water, to which about 1 gram of potassium carbonate was added: then the emulsion of verdigris was added to the boiling solution of arsenic trioxide, which was made acid with acetic acid. At first yellow-green copper arsenite was precipitated: this, on boiling, very gradually changed to the aceto-arsenite, at first crystallizing in a pellicle over the surface; finally, with the addition of a little acetic acid, the whole mass became more dense and crystalline, leaving a blue solution, from which the precipitate was separated by a filter. The precipitate was washed with boiling water, till no arsenic was found in the filtrate on testing the acidulated liquid with sulphuretted hydrogen. The filtrate contained copper, arsenic trioxide, and potassium acetate.

The precipitate was dried at 100° C. for twenty-four hours, and then analyzed.

ANALYSIS No. III.

	Per cents.	Atomic Ratios.
Copper oxide,	32.00	4.33
Arsenic trioxide,	55.63	3.00
Acetic anhydride,	12.31	1.29
	99.94	

The precipitate was of a pale green color, inferior to the samples previously examined, and its specific gravity was much lower.

The above receipt was now varied by substituting the neutral copper acetate for verdigris: the manipulation is much easier than with the basic acetate.

Experiment No. 2.

80 grams arsenic trioxide dissolved in water.
100 „ copper acetate „ „ „

The copper salt was added to the solution of arsenic trioxide: as in the former case, a yellow-green flocculent precipitate was produced, which was gradually converted by boiling into the brilliant aceto-arsenite. The filtrate from the pigment was acid, of a deep blue color, and contained arsenic trioxide, copper, and acetates.

The precipitate was dried at 100° C. as before, and gave on analysis these results: —

Analysis No. IV.

	Per cents.	Atomic Ratios.
Copper oxide,	32.12	4.56
Arsenic trioxide,	56.08	3.00
Acetic anhydride,	10.37	1.07
Hydroscopic water.	.61	
	99.18	

These two salts approximate to Ehrmann's formula, although they vary somewhat from it. In 1858,* "N. Reilter found in four commercial Schweinfurt greens (No. I. was pure, II.–IV. were mixed with heavy spar and gypsum, all four samples showed the presence of free arsenious acid, they were washed before analysis), after deducting the water and impurities: —

	I.	II.	III.	IV.
Copper oxide,	33.97	34.94	33.83	33.65
Arsenic trioxide,	57.52	58.18	54.31	57.93
Acetic anhydride,	8.51	7.88	11.86	8.42
	100.00	101.00	100.00	100.00

"He says it follows from these numbers that Schweinfurt green consists of monarsenite of copper, combined with varying amounts of basic (not *mono*) copper acetate."

It will be seen, by comparison of these results with those obtained by Ehrmann, that they with one exception contain less acetic anhydride and more arsenic trioxide and copper oxide, while they do not approach the composition of the commercial samples analyzed by myself. This is, I think, partly due to an admixture of free arsenic trioxide.

* Jahresbericht der Chemie, 1858, Seite 651.

Experiment No. 3.

The filtrate in Experiment No. 2 contained copper, arsenic trioxide, and acetates. To this solution, in which no precipitate occurred on the addition of more arsenic trioxide, sodium carbonate was added to faint alkaline reaction. A yellow-green precipitate fell, which was collected on a filter, washed until the filtrate was free from arsenic trioxide. Dried, the composition was, —

ANALYSIS No. V.

	Per cents.	Atomic Ratios.
Copper oxide,	50.69	3.31
Arsenic trioxide,	38.13	1.00
Water,	11.88	
	100.70	

This is copper arsenite of the following formula, $Cu_3As_2O_6\ 2H_2O$, with about 4 per cent of hydroscopic water, and contained, as far as could be ascertained by careful testing, *no* acetic acid.

The question then arose, Does sodium arsenite precipitate pure copper arsenite from copper acetate in all cases, or does it also carry down some basic copper acetate with it? This led to

Experiment No. 4.

Copper acetate,	33 grams.
Sodium carbonate,	50 „
Arsenic trioxide,	18 „

The arsenic trioxide was dissolved in the sodium carbonate, and the solution mixed with the copper acetate solution, both being near the boiling point. A yellow-green precipitate fell, the supernatant liquid contained acetates, arsenic trioxide, and carbonates, and was slightly yellow. The precipitate was separated by a filter, and washed till no arsenic trioxide was found in the wash-water. This was much like the product obtained in Experiment No. 3, except that the color was a little brighter and of a bluer shade, and when analyzed gave: —

ANALYSIS No. VI.

	Per cents.	Atomic Ratios.
Copper oxide,	52.06	10.35
Arsenic trioxide,	37.81	3.00
Acetic anhydride,	2.70	.40
Water,	8.21	7.08
	100.78	

This shows that when sodium arsenite acts on copper acetate, if there is not a large excess of arsenic trioxide, we get copper arsenite, which contains some basic copper acetate, as is the case with the copper sulphate under like conditions, and that the acetic acid gives a brighter shade to the color.

To answer the question as to whether an excess of copper acetate would produce, when mixed with arsenic trioxide, a salt containing more basic copper acetate, we have

Experiment No. 5.

Copper acetate,	250 grams.
Arsenic trioxide,	50 „

Dissolved in water separately, and mixed the boiling solutions and boiled an hour. The precipitate was green, the filtrate from it was blue, and contained arsenic trioxide, copper, and acetates. The precipitate had this composition: —

ANALYSIS No. VII.

	Per cents.
Copper oxide,	50.00
Arsenic trioxide,	35.57
Acetic anhydride,	2.47
Water,	11.07
	99.11

This result, deducting hydroscopic water and calculating the per cents anew, gives: —

	Per cents.	Atomic Ratios.
Copper oxide,	52.06	10.80
Arsenic trioxide,	37.04	3.00
Acetic anhydride,	2.57	.39
Water,	8.33	7.38
	100.00	

This is a mixture of copper arsenite and basic copper acetate, almost of exactly the same composition as that obtained by the action of sodium arsenite on copper acetate in Experiment No. 4, and, instead of containing a considerable amount of copper acetate, has a very small amount.

Experiment No. 6.

To the filtrate from the pigment obtained in Expt. No. 5, 50 grams of arsenic trioxide were added and some free acetic acid: a new formation of the well-known color of Schweinfurt green occurred after a prolonged boiling; this was allowed to stand over night in contact with the solution from which it was precipitated; it was then filtered off and washed free from the excess of arsenic trioxide. The filtrate was blue, and acid, containing copper, arsenic trioxide, and acetates; on the addition of more arsenic trioxide, no precipitate fell, but, on neutralizing, one was produced having the color of the one in Expt. No. 3, and it was probably of similar composition, but was in too small an amount for analysis. The composition of the pigment obtained was:—

ANALYSIS No. VIII.

	Per cents.	Atomic Ratios.
Copper oxide,	31.00	7.09
Arsenic trioxide,	54.48	5.00
Acetic anhydride,	11.32	2.00
Combined water,	2.55	2.56
Hydroscopic water,	.65	.70
	100.00	

This is very near the formula,—

$$2(CuOC_4H_6O_3)\ 5(CuOAs_2O_3)+2H_2O,$$

which when calculated in percentages is:—

	Per cents.	Atomic Ratios.
Copper oxide,	31.12	7.00
Arsenic trioxide,	55.43	5.00
Acetic anhydride,	11.43	2.00
Water,	2.02	2.00
	100.00	

This was the first hydrated copper aceto-arsenite obtained, excepting the resulting pigments from Expts. Nos. 5 and 6, which may be considered as mixtures; for, although there was a small amount of water in nearly all samples, it was hydroscopic water, and was entirely driven off by heating to 105° C.

This experiment was repeated, giving:—

ANALYSIS No. IX.

	Per cents.	Atomic Ratios.
Copper oxide,	31.53	7.05
Arsenic trioxide,	55.03	5.00
Acetic anhydride,	10.16	1.76
Combined water,	2.28	2.32
Hydroscopic water,	.64	.60
	100.04	

This is a confirmation of the preceding result, and seems to prove the existence of a hydrated copper aceto-arsenite.

Having experimented on an excess of copper acetate with a small amount of arsenic trioxide, the other extreme was now tried, and, as the proportion was 5 to 1 in preceding case, so here 5 to 1 was used.

Experiment No. 7.

Copper acetate,	25 grams.
Arsenic trioxide,	125 „

Dissolved separately, added the copper solution to the arsenic trioxide, and boiled; the reaction was as in the preceding cases; first copper arsenite, changing to aceto-arsenite; this precipitate was filtered off and washed with hot water; the filtrate contained a trace of copper and a large amount of arsenic trioxide. When the excess of arsenic trioxide was washed out of the precipitate, the latter was dried at 100° C. and analyzed.

ANALYSIS No. X.

	Per cents.	Atomic Ratios.
Copper oxide,	31.19	4.85
Arsenic trioxide,	46.47	3.00
Acetic anhydride,	14.05	1.76
Combined water,	7.05	4.85
Hydroscopic water,	1.15	
	99.91	

This agrees with the formula, —

$$2(CuOC_4H_6O_3)\ 3(CuOAs_2O_3) + 5H_2O,$$

which, calculated in percentages, gives, —

	Per cents.	Atomic Ratios
Copper oxide,	30.90	5.00
Arsenic trioxide,	46.22	3.00
Acetic anhydride,	15.88	2.00
Water,	7.00	5.00
	100.00	

This salt is in color the most brilliant of all the samples in my possession, and of a decidedly different shade from the samples of the formulæ, —

$$(CuOC_4H_6O_3)\ 3(CuOAs_2O_3) \text{ and}$$
$$2(CuOC_4H_6O_3)\ 3(CuOAs_2O_3),$$

being more grass-green, having less blue in it. It comports itself with acids and alkalies in a similar manner to the last-mentioned salt, but is a little more dense; it holds to its five molecules of water strongly, it not being decomposed at 120° C. When heated for a long time at this temperature, it oxidizes slowly and gains steadily in weight. This is probably the salt existing in the commercial samples examined minus the water, and is the nearest approach to them I have been able to make, the exact formula for their production being a trade secret.

"* Wagner states that the formula given by Ehrmann is only empirical, because a portion of the copper is present as the suboxide, and a portion of the arsenic as arsenic acid."

To test this statement, I examined my samples of Schweinfurt green in the following manner: In each case a weighed amount of the green was dissolved in pure hydrochloric acid, made alkaline with ammonia water and "magnesia mixture" added, and in each case a precipitate occurred. After allowing this to stand over night, it was filtered off and washed with aqua ammonia dissolved in hydrochloric acid, and neutralized with ammonia, then acidulated with acetic acid, and acetate of uranium solution of known strength added, testing in the usual way for an excess, with ferrocyanide of potash. The first drop of uranium solution gave a brown coloration when tested with the ferrocyanide, and an excess gave no precipitate, proving beyond a doubt the absence of arsenic pentoxide.

The precipitate obtained by the "magnesia mixture" was doubtless basic magnesium sulphate and magnesia itself.

* Handbook Chemical Technology, Rudolf Wagner, Ph. D. Translated by W. Crooks, F.R.S. Appleton & Co., N. Y., 1872. Page 58.

Therefore I conclude that the formulæ do represent the composition, both empirically and rationally, and that there is *no* suboxide of copper present, as also *no* arsenic acid.

Wagner, after giving Ehrmann's receipt, publishes the following from M. Braconnot: "15 kilos of sulphate of copper ($CuSO_4+5H_2O$) are dissolved in the smallest possible quantity of boiling water, and mixed with a boiling and concentrated solution of arsenite of soda or potash, so prepared as to contain 20 kilos of arsenious acid. There is immediately formed a dirty greenish-colored precipitate, which is converted into Schweinfurt green by the addition of some 15 litres concentrated wood-vinegar. This having been done, the precipitate is filtered off and washed. . . .

"It thus appears that the preparation of this pigment aims first at the least expensive preparation of neutral arsenite of copper, which is then converted into aceto-arsenite of copper, by digesting the precipitate with acetic acid."

Now this is very probably the method, by which the sample obtained from the Massachusetts Institute of Technology was made, and accounts for the basic copper sulphate found in it. The insoluble matter is used to dilute the color and as adulteration.

These latter are therefore impurities, and are to be disregarded in speaking of its composition.

Now with regard to the pure pigment: Ehrmann's analysis is without doubt correct, and is sustained by two samples prepared by myself; but this cannot be regarded as the universal composition of the salt, and does not, as has been already said, cover the commercial samples that I found in the market. Therefore we must look further, and we find there is another salt having the formula, —

$$2(CuOC_4H_6O_3)\ 3(CuOAs_2O_3),$$

in two commercial samples; hence we infer that the composition varies between these salts, that it may be $CuOC_4H_6O_3\ 3(CuOAs_2O_3)$, or $2(CuOC_4H_6O_3)\ 3(CuOAs_2O_3)$, or something between the two; and we also see that the amount of arsenic trioxide may vary considerably, from the difficulty with which it is removed by washing, even with hot water, in process of manufacture.

In the extract from N. Reilter, we have a series of results which vary from any obtained by Ehrmann and myself (with one exception), where the amounts of acetic acid are much less. And he states that Schweinfurt green is copper mono-arsenite combined with varying amounts of basic copper acetate. We have a variance of from

7.88% — 17.82% of acetic anhydride, a variance of nearly 10%. As the salt is crystalline, and is formed out of different proportions of the materials used, with the same composition, as it was in several cases where no *great* change was made, it appears as a definite chemical compound, and the variation is, I think, best explained by considering the existence of several definite salts. Also in three cases I have found water chemically combined, which shows still more variance, but these salts also appear definite, and agree with very simple formulæ.

Pure Schweinfurt green may therefore be composed either entirely of the salt having the formula $(CuOC_4H_6O_3)\ 3(CuOAsO_3)$, or entirely of that having the formula $2(CuOC_4H_6O_3)\ 3(CuOAs_2O_3)$, or may have a composition between the two, from a mixture of these salts, and it may contain combined water having this formula, $2(CuOC_4H_6O_3),\ 5(CuOAs_2O_3)+2H_2O$, or may have the formula $2(CuOC_4H_6O_3)\ 3(CuOAs_2O_3)\ 5H_2O$. And all these results may be varied again still more by a mechanical mixture of arsenic trioxide, from the difficulty of removing the same by washing. That the arsenic is present as trioxide, it contains no arsenic pentoxide so far as I have been able to find in this investigation. The salts of the formulæ $2(CuOC_4H_6O_3)\ 3(CuAs_2O_3)$ and $2(CuOC_4H_6O_3)\ 3(CuOAs_2O_3)+5H_2O$ are more brilliant than the other two with less basic copper acetate in them, the difference being quite marked.

Therefore this beautiful pigment is not so definite as has been previously supposed, but may vary some ten per cent in its amount of acetic acid, twelve per cent in its arsenic trioxide, and five per cent in its amount of copper oxide; while some samples contain chemically combined water, in one specimen going up to seven per cent. And all of these would be taken by an observer for Schweinfurt green, and can only be distinguished by a slight difference in shade of color and chemical composition, which latter shows there exists three definite salts.

In the analyses of this paper, the following methods were employed:

A weighed portion was dissolved in an excess of nitric acid, the solution boiled some time in order to oxidize the arsenic trioxide, the solution was then made alkaline with caustic potash, which precipitated the copper as oxide, which if the acids are all oxidized is black; if not, orange-red, in which case the separation is not as perfect, and it cannot be manipulated with as much ease. as when the oxidation is perfect. The fluid with the precipitate is boiled and

filtered, the precipitate washed with hot water, dissolved in dilute sulphuric acid, and the metallic copper precipitated by a battery.

The filtrate containing the arsenic is made acid with acetic acid, and titrated with uranium acetate solution.

This method was carefully tested against others and itself, and proved to give the most satisfactory results.

The acetic anhydride was determined by ignition with lead chromate as in an organic analysis, collecting the carbonic acid and water, and weighing the same; the excess in weight of water above that formed from the combustion of the acetic acid, gave the total water. The hydroscopic water was determined by drying the salt for three or four hours in an air-bath at 100°—105° C. until a constant weight was obtained, of course deducting the hydroscopic from the total water, gives that which is combined.

I owe my sincere thanks to Professor S. P. Sharples, for his kindness in allowing me the use of his very convenient laboratory, his library, and for some suggestions as the investigation progressed.

Boston, October 24, 1876.

VII.

MILK ANALYSES.

By S. P. Sharples, S.B.

Presented, Nov. 8, 1876.

In my former paper on this subject, read before the Academy last December, I gave the results of the analyses of a number of specimens of milk from the vicinity of Boston. Since that time I have had occasion to examine critically the method of analysis which I was led to adopt by my experiments, as then reported, and the results were so satisfactory that I have extended my investigations further upon the subject of pure milk as produced by cows of different breeds and by the same cow under different conditions. The pure milk for these experiments was kindly furnished me by Dr. E. L. Sturtevant, and was in each case drawn under his own supervision.

The method of analysis followed was first to determine the specific gravity, by weighing 100 cc. of the milk: this was then set for cream; 25 cc. were precipitated by acetic acid and the sugar determined. Five cubic centimetres were carefully weighed, evaporated to dryness, again weighed, the fat dissolved out by benzine, the solids not fat weighed, and then the ash determined by ignition. The caseine was determined by difference, and of course includes all the albumen and other substances of this nature that exist in the solids not fat after the abstraction of the sugar and ash.

The test analyses, with two exceptions, were made on samples of adulterated milk, which were seized during the past year by the milk inspector of the city of Lynn.

Analysis No. I. *April* 1, 1876.

Cream	5%
Sp. Gr.	1.020

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	2.86	2.86	2.860
Caseine	2.99	3.00	2.995
Ash	.42	.42	.420
Solids not Fat .	6.27	6.28	6.275
Fat	2.15	2.18	2.165
Total Solids . .	8.42	8.46	8.440
Water	91.58	91.54	91.560
	100.00	100.00	100.000

In each case, a single precipitation of the caseine and fat for the purpose of determining the sugar was made; but the solution was titrated at least twice, and the average of the results, which never varied more than a cc., taken as the amount of sugar.

This method of determining the sugar has been condemned by many chemists; but, if the precaution is taken of preparing a fresh solution every time a series of determinations are made, the results will, so far as I have experimented, be found to be comparable with each other, and those determinations made in the same sample of milk will agree very closely with each other.

Analysis No. II. *April* 8, 1876.

Cream	6%
Sp. Gr.	1.0215

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	3.45	3.45	3.450
Caseine	2.78	2.79	2.785
Ash	.48	.47	.475
Solids not Fat .	6.71	6.71	6.710
Fat	2.31	2.31	2.310
Total Solids . .	9.02	9.02	9.020
Water	90.98	90.98	90.980
	100.00	100.00	100.000

ANALYSIS No. III. *April* 14, 1876.

Cream			4%
Sp. Gr.			1.022
	Analysis No 1.	Analysis No 2.	Average.
Sugar	3.74	3.74	3.74
Caseine	3.28	3.26	3.27
Ash	.56	.56	.56
Solids not Fat	7.58	7.56	7.57
Fat	2.32	2.34	2.33
Total Solids	9.90	9.90	9.90
Water	90.10	90.10	90.10
	100.00	100.00	100.00

ANALYSIS No. IV. *May* 2, 1876.

Cream			5%
Sp. Gr.			1.023
	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	3.36	3.36	3.360
Caseine	3.25	3.22	3.235
Ash	.50	.50	.500
Solids not Fat	7.11	7.08	7.095
Fat	2.25	2.25	2.250
Total Solids	9.36	9.33	9.345
Water	90.64	90.67	90.655
	100.00	100.00	100.000

ANALYSIS No. V.

Cream			8%
Sp. Gr.			1.0255
	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	3.96	3.96	3.960
Caseine	3.64	3.69	3.665
Ash	.45	.45	.450

Solids not Fat .	8.05	8.10	8.075
Fat	3.30	3.30	3.300
Total Solids . .	11.35	11.40	11.375
Water	88.65	88.60	88.625
	100.00	100.00	100.000

ANALYSIS No. VI. *August* 2, 1876.

Cream 8.5%
Sp. Gr. 1.023

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	3.04	3.04	3.04
Caseine	3.62	3.66	3.64
Ash	.43	.43	.43
Solids not Fat .	7.09	7.13	7.11
Fat	2.18	2.14	2.16
Total Solids . .	9.27	9.27	9.27
Water	90.73	90.73	90.73
	100.00	100.00	100.00

ANALYSIS No. VII. *August* 28, 1876.

(Sample of milk known to be pure.)

Cream 5%
Sp. Gr. 1.030

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	3.94	3.94	3.940
Caseine	4.81	4.82	4.815
Ash	.65	.65	.650
Solids not Fat .	9.40	9.41	9.405
Fat	2.47	2.49	2.480
Total Solids . .	11.87	11.90	11.885
Water	88.13	88.10	88.115
	100.00	100.00	100.000

ANALYSIS No. VIII. *August* 28, 1876.

(Sample known to be pure.)

Cream	18%
Sp. Gr.	1.033

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	4.19	4.19	4.19
Caseine	5.23	5.17	5.20
Ash	.72	.72	.72
Solids not Fat .	10.14	10.08	10.11
Fat	4.35	4.35	4.35
Total Solids . .	14.49	14.43	14.46
Water	85.51	85.57	85.54
	100.00	100.00	100.00

These last two were samples of pure milk furnished by Dr. Sturtevant. After finishing the first analysis of each, I was led to suspect that there must be some error in No. VII., as the total solids are low for a pure milk. I therefore repeated both analyses, taking a second sample from the bottles some five or six hours after the first samples were taken, with the above results. The above eight are not selected analyses, but are all the duplicate analyses I have made up to this time.

These analyses, with the exception of the two last, having been made for legal purposes, it became necessary to compare the results with some standard taken arbitrarily to represent an average pure milk. The standard of 12.5 per cent total solids has been chosen by many chemists, following Mr. Wanklyn in this respect.

It is in all probability a little too low for this vicinity; but it has been adopted for the reason that the courts have generally ruled that, provided a milk-dealer keeps his milk above the quality of the poorest milk that has ever been analyzed, he is to be regarded as selling pure milk, and is therefore not liable to conviction for adulteration. The suit for adulteration being a criminal suit and not a civil suit for damages, the defendant is given every advantage, and the public is forced to be contented if the milk is as rich in total solids as the poorest milk that a half-starved cow was ever known to give. A much more just way to the consumer and to the producer would be to give in the law a certain

standard below which the solids in milk should not be allowed to fall. This might be even as low as 12 per cent. This low figure would be better than the present system, because, in the first place, the consumer would get a better article than he now gets, when all milk that contains over 10.75 per cent of solid matter has to be passed as pure. The producer would fare better also, since by stopping the sale of watered milk, or rather that portion of watered milk that falls below 12 per cent of total solids, the demand would be increased for pure milk. As it is now, the majority of dealers seem to prefer to buy seven-eighths or less of the milk that they need and make up the balance with water, since water costs considerably less than milk.

It seems to be pretty generally conceded that the producer very rarely waters the milk that he delivers to the middlemen or contractors. These deliver to the owners of milk routes, who sell to private families or to stores, from whence it is delivered to the consumer. The owners of the milk routes are the ones who are generally accused of adulterating the milk.

Such a law as that mentioned would, therefore, only diminish their profits, while both the producer and contractor would be better satisfied, for the market would be better and the consumer would be better served. It may be urged, on the other hand, that milk being an uncertain animal product, dependent on various circumstances for its richness and strength, — any one of which circumstances may at any time become abnormal, and so change the value of the milk, — therefore it would be unjust to establish any fixed standard below which the solids should not fall. The answer to this is that the milk of well-fed cows, in good health, rarely, if ever, falls below 11.5 per cent of total solids, and that it will average over 13 per cent of total solids, and that by establishing the standard at 12 per cent, with a margin of half a per cent for exceptional cases, no injustice is done to any one, while the public would be decidedly benefited.

The average milk containing 12.5 per cent of solids should have about the following composition: —

	Theory.	Actual Analysis.
Sp. Gr.	1.030	1.031
Cream	8%	6%
Sugar	4.40	4.32
Caseine	4.30	4.27
Ash	.60	.64

Solids not Fat	9.30	9.23
Fat	3.20	3.27
Total Solids	12.50	12.50
Water	87.50	87.50
	100.00	100.00

For comparison I have annexed the figures as given by an actual analysis of a sample of milk which contained 12.5 per cent of total solids.

In determining the amount of added water for the information of the court, we may use any one of several of the determinations given; that is, we may compare the total solids, when we have the proportion

$$12.5 \; : \; a \; :: \; 100 \; : \; x$$

a representing the amount of total solids found, and x the amount of pure milk in the sample; or we may use the proportion

$$9.3 \; : \; b \; :: \; 100 \; : \; x$$

b represents the amount of solids not fat. A third proportion is

$$4.4 \; : \; c \; :: \; 100 \; : \; x$$

c representing the percentage of sugar as found. In order to show how nearly the amount of added water as determined by these three methods agree, I will give, in addition to the six samples of adulterated milk already given, a few more samples of milk suspected of being adulterated, and then give the amount of pure milk and the amount of added water in each sample as determined by each of the above proportions. I also include in the table three other samples of milk known to be pure, but which would be condemned by one or more of the above tests.

Analysis.	Sugar.	Caseine	Ash.	Solids not Fat.	Fat.	Total Solids.		Sp. Gr.	Cream.
No. IX.	3.52	3.37	.46	7.35	2.45	9.80	90.20	1.025	9
" X.	3.53	3.25	.43	7.21	3.37	10.58	89.42	1.024	9
" XI.	3.52	3.11	.52	7.15	2.10	9.25	90.75	1.024	6
" XII.	3.53	3.59	.48	7.60	2.07	9.67	90.33	1.025	6
" XIII.	3.73	3.40	.48	7.61	2.53	10.14	89 86	1.026	8
" XIV.	4.88	3.48	.64	9.00	2 13	11 18	88.87	1 0815	10
" XV.	4.82	3.54	.57	8.93	2.71	11.64	88.36	1 023	5

Numbers VII., XIV., XV., were known to be pure milk.

Analysis.	From Total Solids.		From Solids not Fat.		From Sugar.	
	Pure Milk.	Added Water.	Pure Milk.	Added Water.	Pure Milk.	Added Water.
No. I.	67.52	82.48	67.47	82 53	65.00	35 00
„ II.	72.16	27.84	72 15	27.85	78.41	21.59
„ III.	79.20	20.80	8 .39	18.61	85.00	15.00
„ IV.	74.76	25 24	76.28	23.72	76.37	23.63
„ V.	91.00	9.00	86.83	13 17	90 00	10.00
„ VI.	74.16	25.84	76.45	23 55	69.09	30.91
„ VII.	95.08	4.92	101.13	—1.13	89.55	10.45
„ IX.	78.40	21.60	79.03	20.97	80.00	20.00
„ X.	84.64	15.36	77.53	22.47	80 23	19.77
„ XI.	74.00	26.00	76.88	23.12	80.00	20 00
„ XII.	77.36	22.64	81.72	18 28	80 23	19.77
„ XIII.	81 12	18.88	81.83	18.17	84.77	15.23
„ XIV.	89.04	10.96	96 77	3.23	110 90	—10.90
„ XV.	93.12	6.88	96.02	3.98	109.55	— 9.55

The figures with the — sign before them show that this ingredient, instead of being below the normal amount, was present in excess.

These cases, with the exception of Nos. V., VII., XIV., and XV., were all carried into court, and convictions were secured. No. V. it was thought not advisable to prosecute, though there could be but little doubt of the adulteration. The other three, as before stated, were pure milk, and each one of these three rises in one determination above the standard chosen; and, if they had been brought to me to be examined as adulterated milks, I should have refused, as I did in the case of No. V., to appear against the seller, as in each case there would be a strong doubt in his favor.

A paper by Dr. Mott, of New York, on the milk from the right and left breasts of women, suggested to me that I should try similar experiments with the different quarters of the udder of the cow. This I have been enabled to do through the kindness of Dr. Sturtevant.

I had previously found that I could, without any extra effort, make from four to six complete analyses a day, if I had a complete set of apparatus for each analysis. Commencing work at 10 A.M., when the milk arrived at my office, the four analyses have been completed, except the reading of the volume of cream, by 6 P.M. Analyses Nos. XVI., XVII., XVIII., and XIX., were of milk yielded by the Ayrshire cow "Model of Perfection." She was eleven years old, and calved Dec. 31, 1875. Evening's milk, Aug. 13, 1876.

The milk was drawn from each teat into a separate vessel, and was brought to me next morning.

XVI.	Right forward teat,	yield	907.	grams.
XVII.	Left forward teat,	yield	577.	„
XVIII.	Right rear teat,	yield	680.	„
XIX.	Left rear teat,	yield	577.	„
		Total yield	2741.	„

	XVI.	XVII.	XVIII.	XIX.	Average.
Cream	25.	42.	29.	24.	28.1
Sp. Gr.	1.025	1.024	1.026	1.028	1.0257
Sugar	4.09	2.18	3.44	4.20	3.72
Caseine	4.48	6.58	5.00	5.59	5.11
Ash	.68	.61	.66	.67	.66
Solids not Fat . . .	9.25	9.37	9.10	10.46	9.49
Fat	5 59	4.43	4.39	3.84	4.68
Total Solids . . .	14.84	13.80	13.49	14 30	14.17
Water	85.16	86 20	86.51	85.70	85.83
	100.00	100.00	100.00	100.00	100.00

The sugar in No. XVII. was tested a second time with the same results.

Analyses Nos. XX., XXI., XXII., XXIII. The above results varied so much that it was desirable to repeat this experiment, which was accordingly done with another cow, with the following results: —

Ayrshire cow "Tabitha;" feed, 4 quarts cob meal per day, hay, and corn fodder; age, 2½ years; calved last spring. Evening's milk, Nov. 19, 1875. Analyzed Nov. 21, 1876.

XX.	Right forward teat,	yield	624.	grams.
XXI.	Left forward teat,	yield	624.	„
XXII.	Right rear teat,	yield	680.	„
XXIII.	Left rear teat,	yield	737.	„
		Total yield	2665.	„

	XX.	XXI.	XXII.	XXIII.	Average.
Cream, vol. p. c.	14.	11.	13.	10.	11.9
Sp. Gr.	1.032	1.031	1.0306	1.0315	1.031
Sugar	4.90	5.00	4.72	4.88	4.87
Caseine	3.53	3.42	3.61	3.48	3.51
Ash	.59	.57	.61	.64	.60
Solids not Fat	9.02	8.99	8.94	9.00	8.98
Fat	3.32	3.00	2.73	2.18	2.77
Total Solids	12.34	11.99	11.67	11.18	11.75
Water	87.66	88.01	88.33	88.87	88.25
	100.00	100.00	100.00	100.00	100.00

The variation in this case consists mainly in the amount of fat. This variation, as will be seen, amounts to 1.21 per cent. The averages for both the above milks were found by ascertaining the total weight of each product given by the teat, adding the four weights together and dividing by the total weight of milk yielded.

It is evident from these experiments that each quarter of the udder yields a milk that may differ considerably from that given by any of the other quarters. This, however, has only a scientific interest, as in practice the four quarters are drawn simultaneously and the average result is used.

Some further experiments were tried in reference to the influence of breed and feed on the quality of the milk. These are far too few in number to base any opinion on; but, so far as I have been able to carry them, they show the need of extended experiments on this subject, — experiments which should be carried over the space of several years, with analysis at least once a week, careful records being kept of temperature of the air, state of the weather, and general condition of the cow; and a sufficient number of cows of each breed should be employed, that the individual equation of the cow should be eliminated so far as possible. To be comparable, these analyses should be either made by one person, or, if made by several, they should be made by the same method, and these persons should compare their working by making several simultaneous analyses of the same sample of milk.

Analysis No. XXIV., Ayrshire cow "Georgie;" calved July 7, 1876; food, pasture, fodder corn, and six quarts of shorts. Evening milk, Aug. 7, 1876.

Analysis No. XXV., Ayrshire cow "Georgiana;" calved July 19; food the same as last. Evening milk, Aug. 7, 1876.

Analysis No. XXVI., Ayrshire cow "Georgiana;" feed for a week previous, green fodder corn and grass. Evening milk, Aug. 19, 1876.

Analysis No. XXVII., cow "Georgiana;" feed for the previous week, green fodder corn, grass, and three quarts corn meal per day. Evening milk, Aug. 28, 1876.

Analysis No. XXVIII., cow "Georgiana;" feed for the previous week, grass, and five quarts of shorts, and one quart of corn meal per day. Evening milk, Sept. 3, 1876.

These two cows were full-blood Ayrshire, mother and daughter. "Georgie" was imported, and "Georgiana" was calved in this country.

	XXIV.	XXV.	XVI.	XVII.	XVIII.	Average.
Cream vol. p. c.	14.	17.	20.	5.	6.	12.4
Sp. Gr. . . .	1.029	1.031	1.030	1.030	1.031	1.0302
Sugar	5.00	5.19	5.20	8.94	4.32	4.73
Caseine . . .	3 60	4.13	3.34	4.82	4.27	4.03
Ash	.59	.67	.60	.65	.64	.63
Solids not Fat .	9.19	9.99	9.14	9.41	9 23	9.39
Fat.	3.09	4.20	4.34	2.48	3.37	3.48
Total Solids .	12.28	14.19	13.48	11.89	12 60	12.87
Water. . . .	87.72	85.81	86.52	88.11	87.50	87.13
	100.00	100.00	100.00	100.00	100.00	100.00

Analysis No. XXIX., Jersey cow "Henny;" calved July 17, 1876; food, pasture and green fodder corn, two quarts mixed corn and oat meal, and one quart shorts per day. Evening milk, Aug. 6, 1876.

Analysis No. XXX., Jersey cow "Danseuse;" calved May 11; same feed as No. XXIX. Evening milk, Aug. 6, 1876.

Analysis No. XXXI., Jersey cow "Henny;" feed for the previous week, corn fodder and pasture. Evening milk, Aug. 19.

Analysis No. XXXII., Jersey cow "Henny;" food, pasture and corn meal. Evening milk, Aug. 27, 1876.

Analysis XXXIII., cow "Henny;" food, pasture and six quarts of shorts per day. Evening milk, Sept. 3, 1876.

	XXIX.	XXX.	XXXI.	XXXII.	XXXIII.	Average.
Cream vol. p. c.	27.	21.	22.	18.	18.5	20.8
Sp. Gr. . . .	1.027	1.031	1.030	1.033	1.030	1.030
Sugar	4.20	4.57	5.67	4.19	4.81	4.69
Caseine . . .	4.42	3.78	2.64	5.17	3.83	3.97
Ash	.59	.59	.62	.72	.61	.62
Solids not Fat .	9.21	8.94	8.93	10.08	9.25	9.28
Fat	4.72	6.61	5.07	4.35	4.78	5.12
Total Solids . .	14.01	15.55	14.00	14.43	14.03	14.40
Water	85.99	84.45	86.00	85.57	85.97	85.60
	100.00	100.00	100.00	100.00	100.00	100.00

It appears from the average of these two series of analysis that in this experiment the two breeds of cows gave milk that averaged almost exactly the same composition, with the exception of the yield of fat; the Jersey giving on the average nearly one half more fat than the Ayrshire. The average result of the thirty-four analyses of pure milk, twenty-two of which were reported last December, and twelve now, is as follows:—

Sp. Gr.	1.030
Cream vol. p. c.	13.8
Sugar	4.82
Caseine	4.06
Ash	.65
Solids not Fat	9.53
Fat	4.62
Total Solids	14.15
Water	85.85
	100.00

With these analyses to judge from, it seems to me that an inspector of milk is fully justified in asking a conviction from the courts, if, when the theoretical milk containing 12.5 per cent of solids is taken as a standard, each of the three proportions starting from total solids, solids not fat, and sugar, show an addition of fifteen per cent or over of water.

No specimen of pure milk that I have ever examined, or that I can find any records of, fails to the extent of fifteen per cent of indicated adulteration in all three of these particulars. And I may add still further, although the specific gravity of a milk is not regarded as a reliable indication of its purity, that, in every case of adulterated milk I have met with, the inspector was justified in his seizure, if the sp. gr. fell below 1.026.

The mistake is sometimes made of considering the estimation of added water as an absolute determination, entitled to the same weight as the actual analysis. But it must be evident to any one, on a few moments' reflection, that these estimations cannot be so regarded, and that they are only approximations, whose chief value is to show the courts how much the milk falls below a milk of fair quality; and, when taken in connection with the fact that pure milk never falls so far below this standard, they enable the court to judge intelligently whether there are fair grounds for considering the sample to be adulterated.

Boston, Nov. 27, 1876.

APPENDIX.

It having been suggested that the first run of the milk of a cow was much poorer than the strippings, and therefore a milkman, who was desirous of proving that his milk was unwatered, might procure an analysis of such a specimen, the following experiment was tried: —

Analysis No. XXXIV., cow "Georgiana," right forward teat. Even-

	Analysis No. XXXIV.				Average.
	No. 1.		No. 2.	No. 3.	
Sp. Gr.	1.029		1.032	1.027	1.029
Cream	6%		9%	11%	8%
Sugar	4.49		4.80	4.50	4.61
Caseine	3.06	3.01	4.25	3.90	3.65
Ash	.54	.54	.58	.54	.55
Solids not Fat	8.09	8.04	9.63	8.94	8.81
Fat	1.78	1.84	3.03	4.03	2.61
Total Solids	9.87	9.88	12.66	12.97	11.42
Water	90.13	90.12	87.34	87.03	88.58
	100.00	100.00	100.00	100.00	100.00

ing, Dec. 3, 1876. The milk was divided into three portions, as follows. 319 grams were first drawn into one bottle, 274 grams were drawn into a second, and the remainder of the milk, 100 grams, was drawn into the third bottle. These three samples of milk were brought to Boston next morning and analyzed, with the following results. No. 1 proving so poor, a second analysis was made of it. This did not change the figures to any amount.

The first drawing in this case, while showing a deficiency of total solids, and solids not fat, nevertheless has rather more than the average amount of sugar, so the rule laid down would fail to condemn this as a watered milk. No one, however, would hesitate a moment in saying that it was a very poor article indeed. "Georgiana's" milk, as shown all through this paper, is not a very rich milk.

The near approach of Ayrshire milk to woman's milk is worthy of remark. The average of many analyses of woman's milk, as given by different authors, is as follows: —

	Colored Woman's Milk. Average of 12 Analyses, by Mott.	White Woman's Milk. Average of 89 Analyses, by Vernois and Becquerel.	White Woman's Milk. Average of 14 Analyses, by Simon.	White Woman's Milk. Average of 14 Analyses, by Tidy.
Sugar	5.71	4.364	4.82	4.265
Caseine	3.32	3.924	3.48	3.523
Ash	.60	0.138	0.23	0.285
Solids not Fat	9.63	8.426	9.11	8.073
Fat	4.03	2.666	2.53	4.021
Total Solids	13.66	11.092	11.64	12.194
Water	86.34	88.908	88.36	87.806
	100.00	100.00	100.00	100.00

These differ fully as much among themselves as any one differs from the average of Ayrshire milk, as given. Any tampering with Ayrshire milk, such as adding sugar and water to it, in order to make it more nearly resemble woman's milk, will therefore evidently do more harm than good: it is free from the excess of fat which oftentimes renders Alderney milk unfit for food for delicate children, and I have been assured by those who have used it that it makes an excellent substitute for woman's milk. For children's food, it evidently needs

nothing done to it, except warming it slightly, so as to take the chill off.

In this connection, I think I am justified in saying that no one cow's milk is as uniform in composition as the milk of a herd of cows, and that, if a uniform diet is wished for a child, it will be much better secured by mixing the milk of a number of cows, than when it is attempted by trying to secure the milk of a single cow. Since, as we see, the milk of any one of the cows taken varies very considerably.

BOSTON, Dec. 7, 1876.

VIII.

ON A NEW MODE OF MANIPULATING HYDRIC SULPHIDE.

BY JOSIAH P. COOKE, JR.,

Erving Professor of Chemistry and Mineralogy in Harvard College.

Presented May 30th, 1876.

IN chemical laboratories, where instruction in qualitative analysis is given to large numbers on the class system, the use of hydric sulphide gas as a reagent is attended with grave inconveniences. These evils can in great measure be avoided by substituting for the gas a solution of the reagent in water, saturated at the ordinary temperature and pressure of the air; when, as is well known, one volume of water dissolves about 3.4 volumes of the gas (measured at 15° C. and 76 cm.). Such a solution was for a long time used in the laboratory of Harvard College. It was prepared in a long series of two *litre* bottles connected by glass tubes in the usual way, and the solution was kept in the laboratory in a large tubulated glass flask, from which it was drawn by the students, as occasion required. This solution answers almost every purpose for which the reagent is used in the ordinary course of qualitative analysis, and the few conditions under which it does not give satisfactory results can be easily avoided. Moreover, in ease of application and promptness of effect it has all the advantages of a liquid reagent; and the only inconvenience its use involves is an occasional evaporation of a solution, which the dilution by the reagent may render necessary. Of course a solution of hydric sulphide is liable to oxidation, and soon becomes turbid in contact with the air; but this change can be easily avoided by fitting to the neck of the flask (in which the solution is kept), by means of a rubber stopper, a glass tube dipping under the liquid, and connecting this tube with one of the vents of illuminating gas in the laboratory.

For quantitative work, and for the preparation of chemical products, when considerable quantities of metallic sulphides must be precipitated, a solution of hydric sulphide, saturated under the ordinary pressure of

the air, is inconveniently dilute; and two years since we described a simple method by which a solution concentrated under pressure could easily be prepared with the ordinary laboratory appliances. A heavy glass bottle of about four litres' capacity served as a generator, and from this the gas passed through a wash-bottle into two other bottles of the same size and strength as the first. The intermediate bottle was three-fourths filled with water, while the last served simply as a gasholder. The connections were so arranged that the gas, after bubbling up through the water, was delivered at the top of the gasholder; and, by a tube uniting the bottom of the gasholder with the water-pipes of the laboratory, the interior of the apparatus could be submitted to the pressure of a column of water sixty feet high. The gasholder was also provided with an exit tube, which could be closed by a compression cock. The connecting tubes all passed through rubber stoppers which were firmly wired to the necks of the bottles, and the water-bottle was connected with its neighbors by two lengths of stout rubber hose so that the water could be shaken up with the gas without disturbing the rest of the apparatus. In order to saturate the water with hydric sulphide, a charge of ferrous sulphide sulphuric acid and water sufficient to yield at least three times the amount of gas theoretically required was placed in the generator, and, after the connections were made, the gas was allowed to stream through the apparatus until all the air was displaced. The exit tube of the last bottle was then closed, the water pressure turned on and the water-bottle frequently shaken, until absorption ceased, and the aqueduct water — at first forced by its pressure into the gasholder — was driven back into the pipes. Before dismounting the apparatus, the rubber connectors were all closed by compression cocks, and care was taken to vent the generator gradually. Moreover, the connectors of the water-bottle were so arranged that when the apparatus was dismounted a short piece of rubber hose was left attached to each orifice of the bottle, both of which were closed by compression cocks. To one of these a vent tube was subsequently attached, and by this the solution was drawn off at pleasure, as from a soda-water siphon.

This simple apparatus was constantly used by us for two years, and served an excellent purpose; but it was found that after the glass generators had been charged several times they were liable to burst under the same pressure which at first they had readily sustained. The same accident never happened to the other bottles. But of course, if the pressure is long continued, bottles of glass of the size named, however well made, would be liable to such an accident; and, if the

apparatus is to be remounted, it would be better to use a metallic vessel for the generator, and to cover the glass bottles with some kind of netting. The experience with the glass apparatus led us to seek to adapt to the same purpose some one of the various soda-water apparatuses which are greatly used in the United States for the production of effervescing drinks. After examining several of the patterns in the market, we selected for trial the one represented below, which is manufactured by the firm of John Matthews, of New York, at their establishment, — First Avenue, 26th and 27th Streets, — in that city. The apparatus was designed by them for preparing that overcharged aqueous solution of carbonic dioxide, which in the United States is familiarly called soda-water; but with a very slight modification it can be used with equal efficiency for the preparation of a similar solution of hydric sulphide. We have worked out the details of the process, which this new application involves, and publish them with the hope that the apparatus may be found of as great value in other laboratories

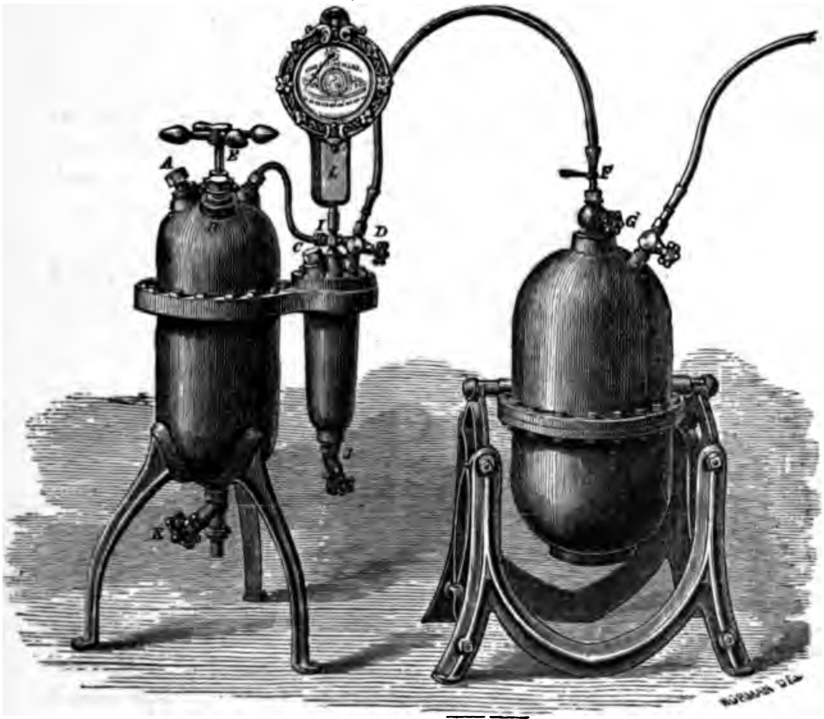

Fig. 1.

as in our own. The wood-cuts are taken from the catalogue of the firm, who have kindly loaned the blocks for this paper; and we would here express our obligations to them for their great courtesy and liberality during the whole course of our experiments.

The apparatus consists of two parts, the generator and the fountains; and in Fig. 1 the generator is represented connected by a rubber hose with one of the fountains, of which in practice we use three, connected in a line by similar lengths of rubber hose, like so many Woolf's bottles. In the figure, only the first of the line is represented, which is set on trunnions in a frame, in order to facilitate the agitation of the water and the gas. Only one of these frames, however, is required, to which the other fountains can readily be transferred. A section of the generator is represented in Fig. 2. It is made of cast iron, and in

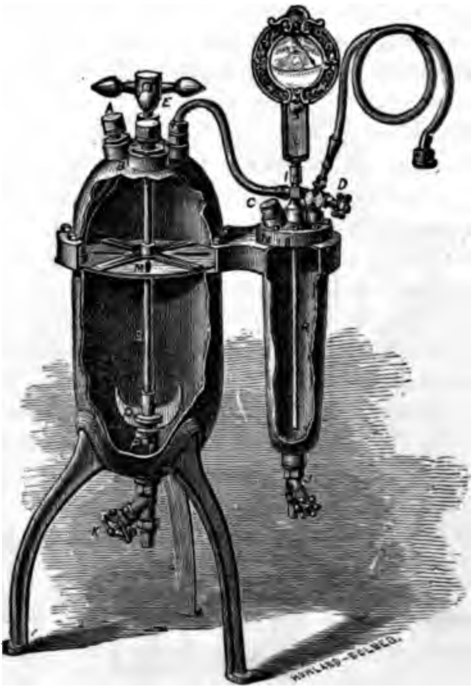

Fig. 2.

two parts (readily distinguished in the figure), which are firmly bolted together, so as to confine in its place the bell-metal plate M, which separates the upper from the lower chamber. In the lower chamber is placed dilute sulphuric acid, which is poured in through the bung A.

In the upper chamber, and resting on the plate, is placed coarsely powdered sulphide of iron, which is put in through the bung B. Through the plate M, and on two lines at right angles to each other, there are cut radial slits, $\frac{1}{8}$ an inch wide, which are guarded by four iron arms. These arms are attached to the agitator shaft S, and move over the surface of the plate, alternately covering and uncovering the slits, when the handle E is turned. To the lower end of the same shaft is fastened the agitator O, which is turned simultaneously with the arms just mentioned. After the apparatus has been charged, it is evident that by turning the handle the sulphide of iron may be sifted down at pleasure into the acid water below; and the handles and arms are so disposed that when the bungs are uncovered by the handles the slits are covered by the arms. From the generator, the gas passes through the washer R, whose relations to the apparatus, as well as that of the pressure gauge, are evident from the figure. The generator is lined with lead, and the rest of the apparatus, including the bell-metal plate M, with pure tin. The lead lining of the generator is seamless and very heavy, and all the cocks are lined with block tin tubing. Of the various valves, bungs, and stuffing boxes indicated in the figure, it is unnecessary to speak in detail. It is sufficient to say that they are of excellent workmanship, and during a year's trial have kept perfectly tight. The charging bung, B, however, is closed by a safety cap of peculiar construction, which deserves special mention, because it insures the safety of the apparatus. The cap is represented by Fig. 3, and a section is given in Fig. 4. It will be seen by the last that the escape of the compressed gas from the generator through the apertures *d* is only prevented by a thin disk *a*, which is shown in detail by Fig. 5.

Fig. 3.

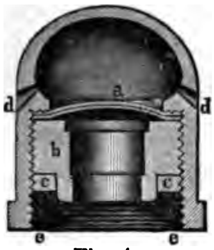

Fig. 4.

Fig. 5.

This disk is made of two thin plates: the lower one, which comes in contact with the acid spray, is of lead, and the upper one of silvered copper, whose thickness is so adjusted that it must be at once ruptured if the pressure in the apparatus should become unduly great.

Although the so-called soda-water fountains — in which the solution of the gas and water is made — have all in general the same simple relation of parts, they are constructed of very different materials and after very different methods. The outside shell may be either of hammered copper or of some form of iron, and this may be lined with tin, enamel, or glass. After having determined by experiment that a solution of hydric sulphide — especially when some carbonic dioxide is added — exerts no action on a surface of metallic tin, except a very slight and superficial staining, we selected as best adapted to our purpose the steel fountains, also manufactured by the firm of John Matthews, Fig. 6. These are made of plates of steel, united in a

Fig. 6.

peculiar way invented by themselves so as to secure with comparative lightness very great strength. They are lined on the inside with sheet tin, and the tin lining forms an independent vessel, which alone is connected with the bungs. The tubes and valve cocks are also either made or lined with tin, so that the solution never comes in contact with any other metal. For making ordinary soda-water, the fountain requires only a single valve, which connects with a tube leading to the bottom of the vessel, and this serves both to charge the fountain and to draw

off the solution when made. But since a solution of hydric sulphide is rendered turbid if left in contact with even a small quantity of air, and since a variable amount of free hydrogen is always formed by the action of sulphuric acid on common sulphide of iron, it was necessary for our purpose to add to the ordinary fountain a vent cock as shown in the last figure. This enables us to connect together several fountains after the manner of Woolf's bottles as already described, and, by passing the current of gas through the whole line, to drive out all the air originally in the apparatus, as well as the free hydrogen subsequently evolved. Moreover, in the preparation of the solution of hydric sulphide, the generator should be much larger relatively to the fountains than in the preparation of soda-water. Thus we use for charging the so-called six-gallon steel fountains, the "Upright Generator" known as No. 40, which has a capacity below the diaphragm of sixty litres. It should be here stated that the fountains are only rated at two thirds of their total capacity, which is the volume of soda water which is ordinarily made in them. They should never be more than three-fourths filled with water. But, even with this liberal allowance for gas room, the six-gallon fountains referred to will hold twenty-five litres of water. It may also be stated, although the fact must be evident, that a single large fountain will not give as good results as several small ones of equal capacity; since in expelling the air and free hydrogen, as we have described, there would be a considerable loss of material, if only one fountain were used. Still, in laboratories where the consumption is not great, the loss is not important; and the smallest "Upright Generator," with one six-gallon fountain, will be found to be a perfectly satisfactory apparatus.

Assuming first that the larger apparatus is used, the method of charging is as follows: The large generator is too heavy to be readily moved, and should be placed so that the discharge valve will empty directly into a drain. Water also should be brought to the apparatus by hose, — if possible, both hot and cold water, — not only for convenience in charging, but also in washing. Finally, there ought to be a good flue in the neighborhood, into which the waste gas may be discharged. The apparatus having been thus established, the three fountains — first rinsed out — are filled each with twenty-five litres of distilled water, and, the valves having been secured, the fountains are connected with each other and the generator by means of stout rubber hose as already indicated, and the vent valve of the last fountain is connected with the flue by a length of common gas hose. The generator is then charged as follows: The handle is first placed so as to uncover the bungs and cover the slits in the diaphragm. Through the bung A is

now poured 40 litres of *hot* water, heated to between 70° and 80° C., and then 5 litres of common oil of vitriol are poured very cautiously into the same bung through a lead funnel with narrow spout provided for the purpose. The acid water will thus be heated nearly to the boiling point, and its capacity of dissolving ferrous sulphate raised to the maximum. Next 6 kilogrammes of sulphide of iron — previously sufficiently pulverized to pass through a wire sieve with eight meshes to the inch, and mixed with two kilogrammes of marble powder — is run through a wide-mouth funnel into the bung B. The bungs having been now all closed, the joints of the apparatus tested, the exit valve D of the generator and all the valves of the fountains opened, a small amount of the powder is sifted down into the acid water by turning the handle not more than a single revolution, always taking care to leave it so that the slits of the diaphragm shall be left covered. The gas is then allowed to stream through the apparatus, and tested as it escapes into the flue, until it burns without explosion, using a small pneumatic trough for that purpose. The air is now nearly expelled, and the escape of gas should be reduced by the last vent valve until the current only supplies a small jet, which may now be attached and lighted with safety, and by the size of this flame the vent may afterwards be regulated. The handles are now slowly turned, and the pressure in the apparatus carried up to about 120 pounds. The valves of the fountains and the valve D of the generator are now all closed, and the two last fountains detached, leaving the first (which is mounted on a frame as represented in Fig. 1) united to the generator as before. This is now rocked for several minutes to and fro, in order to thoroughly agitate the water with the gas. The stop valve G should then be opened, and then the valve D (very gradually), so that the gas may be admitted slowly to the fountain. The valves are then again closed, and the agitation renewed, and the same operation is repeated several times until no more gas is absorbed by the water in the fountain, the pressure in the generator meanwhile being maintained at 120 lbs., by turning the handle. The first fountain is then removed, and the same process repeated with each of the others. At the close of the operation, after all chemical action has ceased, there remains in the generator — both free and dissolved in the liquid residue — a large volume of hydric sulphide gas. This we economize by venting the generator slowly through Woolf's bottles containing aqua ammonia, and thus preparing at the same time ammonic sulphide. It is not unimportant to add that the generator should be emptied before it cools, and the ferrous sulphate has time to crystallize. The discharge valve R should then be removed, and the whole apparatus thoroughly

washed out. If the valve becomes clogged, it can generally be cleared by developing pressure in the generator by means of a small charge of ground marble. Otherwise, after the pressure has been relieved, and the upper valves and bungs closed, the discharge valve must be cautiously removed, and an opening forced through the lower bung. Such details are necessary in order that others may profit by our experience; but, lest the details should convey the impression that the apparatus is complicated, and that the process requires skilled labor, it may be stated that in this laboratory the apparatus is entirely in charge of a laboratory servant, and may be managed by any workman of ordinary intelligence. It does not require more than four hours to work over a single charge, and this yields 75 litres of hydric sulphide solution under a pressure of 120 lbs. According to our experience, this supply lasts with a class of one hundred students in qualitative analysis about a month. For laboratories where the classes are much smaller than this, we should recommend the smallest size generator, which may be used with a single six-gallon fountain. The smaller apparatus is managed in precisely the same way as the larger, only taking one half the quantity of materials. It is important as before to wash out in the first place all the air, and to maintain a small current of gas through the vent valve of the fountain while the pressure in the apparatus is rising. This of course entails some loss of hydric sulphide; but the chief loss is caused by the venting of the generator, and all this gas may be utilized for the preparation of alkaline sulphides as described above, or this waste gas may be used for washing out the air from a second fountain, and thus preparing it for a subsequent charge.

For dispensing the reagent in our *qualitative* laboratory, we place the fountain in a cupboard and connect it by a block-tin tube with a so called "draught column," Fig. 7, in the ventilating hood above. From this each student draws the reagent as it is required. In quantitative work we may draw the charged water directly from the fountain into the midst of the solution to be treated, using simply a common rubber hose terminated by a glass tube which dips under the surface of the liquid: the hose is attached to the nipple of a cap which screws on to the valve of the fountain, and by confining two or more disks of linen cloth between the cap and the head of the valve (like washers) we can filter the solution as it flows out. It is more convenient, however, to distribute the reagent to advanced students in the well-known soda-water siphon, Fig. 8. These require no description, but as the simple apparatus used for filling the siphon is not yet a familiar object in chemical laboratories, we give a figure of the

apparatus (Fig. 9), taken, like our other cuts, from the catalogue of John Matthews. By pressing the foot on a pedal shown at the base

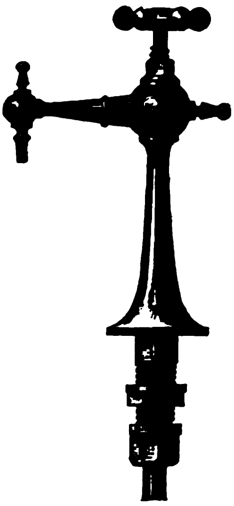

Fig. 7.

Fig. 8.

of the apparatus, the siphon — confined in a cage — is raised, so that its mouth is forced tightly against one opening of a valve of peculiar construction, the second opening of which is united by a block-tin tube to a fountain; while at the same time the handle of the siphon is pressed back. On now pushing the upper lever shown in the cut to the right, the valve of the fountain having been previously opened, a connection is made between the fountain and the siphon; when the charged water rushes into the latter, condensing the air to a fraction of its original volume. If next the same lever is pushed momentarily to the left, the first connection is closed; while a vent is opened, through which the condensed air rushes out into the atmosphere before the gas in solution has time to escape, and then on pushing back the handle a further portion of liquid enters, nearly filling the interior of the bottle. Lastly, on raising the foot, the valve of the siphon shuts at the same time that the bottle is lowered and released from its cage, — the whole process being the work of a few seconds. At the first filling, there sometimes remains a small amount of air in the siphon, so that the solution becomes slightly turbid on standing; but this effect of oxidation can be easily avoided by using a sufficient amount of marble powder

in charging the generator. This siphon unquestionably affords the most convenient mode of using hydric sulphide; and for a private laboratory a single siphon, well charged, will afford as ample a supply as will ordinarily be needed. It is greatly to be hoped that our manufacturing chemists may soon find an advantage in supplying this important reagent in such an elegant form.*

Fig. 9.

When the water is charged as directed above, it of course holds in solution, besides hydric sulphide, a considerable volume of carbonic dioxide; and if, under any circumstance, the presence of this last gas would produce an injurious effect, the marble powder can be simply omitted in charging the generator. In almost all cases, however, the carbonic dioxide exerts a very beneficial influence, and in several ways. In the first place, it insures the non-action of the hydric sulphide on the metallic surfaces of the apparatus. In the second place, it protects the solution from the action of the air when it is drawn into an open vessel, so that after a metallic sulphide has been precipitated by an excess of the reagent, the products may be digested in an open flask or beaker without fear of oxidation. In the third place, the carbonic dioxide adds greatly to the tension of the confined gas, and enables us to develop sufficient pressure to charge the siphon without unnecessarily increasing the strength of the solution of hydric sulphide.

Chemical Laboratory of Harvard College, 1876.

* All the apparatus here described may be obtained from the firm of John Matthews, First Avenue, 26th and 27th Streets, New York, at very reasonable rates. Be careful in ordering to state the use to which the apparatus is to be put, with the caution that no silver plating or lead paint should be used upon it.

IX.

ON THE PROCESS OF REVERSE FILTERING AND ITS APPLICATION TO LARGE MASSES OF MATERIAL.

By Josiah P. Cooke, Jr.,

Erving Professor of Chemistry and Mineralogy in Harvard College.

Presented May 30, 1876.

By reverse filtering is meant a process of filtration in which the liquid to be filtered is drawn upwards instead of flowing downwards in the usual way. Such a system is often used in the arts, as when a porous septum is attached to the mouth of a suction pipe; or as in the small portable filters so useful to travellers, by which clear water may be sucked up from a muddy pool or turbid stream. These last suggested the application of the same principle in chemical analysis to the treatment of those precipitates which are usually weighed on a dried filter. In such cases, it is of course essential that the weight of the paper disk used as a filter should remain invariable; and this constancy can be best secured by making the disk as small as possible. If the filter is large, it is impossible to have any confident assurance of the constancy of its weight, however great the care that may be taken to secure a similarity of hygrometric conditions at the two weighings; and hence it has not hitherto been practicable to determine on a dried filter the weight of any considerable quantity of a precipitate with accuracy. But, in the process of reverse filtering, we can both wash and collect very large masses of precipitates with a filter not more than an inch in diameter; and if, before drying, these little disks of paper are soaked in dilute hydrochloric acid, and afterwards thoroughly washed in water, their weight remains practically invariable. Indeed, it is not necessary to enclose the filter in a weighing tube, or to pay any special regard to its hygrometric conditions other than to keep the usual drying materials in the balance case. The only liability to alteration of weight would arise from the dissolving of soluble material in the paper, and this may be wholly prevented by previously washing the disks as just described.

In the early part of 1873, having occasion to determine large quan-

tities of sulphide of antimony, we in the first place employed the porous filtering cones described by Prof. C. E. Munroe; * but we found these both too limited in capacity, and too susceptible to hygroscopic influences, to give the degree of accuracy we required. We were therefore led to devise the following apparatus, which Figures 1 and 2 will help us to describe. The most essential part of this apparatus is the platinum "rose" represented by Fig. 1. This is cemented by sealing-wax to the end of a glass tube, and to its perforated base the small filters are applied. The glass tube is so cemented

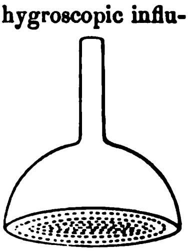

Fig. 1.

into the neck of the "rose" that the end may reach quite down to the perforated plate, and thus draw up all the liquid which collects in the hemispherical cup. Moreover, the perforated plate has an unbroken rim about $\frac{1}{16}$ of an inch wide around the edge, which is sufficient to prevent any solid particles from creeping by the edges of the paper disk. The success and rapidity of the filtering depend on the proper construction of the perforated disk, and we obtained the best results only after several trials. The holes should be smoothly perforated about $\frac{1}{50}$ of an inch in diameter, and as numerous as possible, leaving the unbroken rim described above. After the perforations are made, the face of the plate should be ground perfectly smooth. We use two sizes of these "roses," in one of which the hemisphere is $\frac{7}{8}$ of an inch, and of the other $1\frac{1}{4}$ inches in diameter; but the smaller is the more useful, and is sufficiently large for all ordinary purposes. A disk of washed Swedish filtering paper, $\frac{7}{8}$ of an inch in diameter, weighs only about 20 milligrammes; and, to give an idea of the rapidity of the filtration, it is sufficient to say that, under a pressure of 50 centimetres of mercury, these filters will pass from 20 to 30 litres of clear water in an hour. We have been greatly indebted to Messrs. Johnson, Matthey, & Co., of Hatton Garden, London, for the care they have taken in the construction of these "roses;" and they can be procured of them through the mail. The cost of the smaller size is fifteen shillings sterling. The construction of the rest of the apparatus is made clear by Fig. 2. One of the stems of a glass three-way tube is clamped to an arm which can be raised or lowered on the vertical bar of an elevating stand by a rack and pinion movement, which ought, however, to be so loose, that the arm can be pushed suddenly up when necessary. By its second stem, the three-way tube is connected

* American Journal of Science, May, 1871.

by a rubber hose with a large glass bottle, in which a partial vacuum is maintained by a Bunsen pump, but this connection can be closed by

Fig. 2.

a compression cock. The third stem, which makes a connection with the atmosphere, is closed by a rubber connector and nipper tap, and serves to suddenly relieve the pressure in case the filter slips or breaks. From the first and vertical stem of the three-way tube below the clamp is suspended the glass tube, having the rose at its end. The suspension consists of a rubber connector, so long that it can be bent double and the rose inverted, and so stout that when thus bent the connection with the bottle is completely closed. When inverted, the tube of the rose rests against the thumbscrew of the pinion, and is thus confined.

In order that we may make clear the mode of using the apparatus, let us assume that five grammes of antimonious sulphide have been precipitated in a glass beaker, holding two litres of liquid, and that the precipitate has settled, — as it will after boiling, — leaving the supernatant liquid perfectly clear. A partial vacuum having been formed

in the bottle, and the beaker having been placed on the stand, we begin by attaching the paper disk to the base of the rose, moistening it for the purpose with water, and forcing it with the thumb against the perforated plate until the adhesion is complete at every point. It is important that the disk should not overlap the edge of the plate; and, if the plate has been made as described, it will adhere tightly without so doing. The compression cock is then slowly opened; and, as soon as the sound indicates that the air is being sucked through the filter, the base of the rose is quickly sunk under the liquid, and constantly lowered by the rack and pinion movement, as fast as the liquid is drawn off. The supernatant liquid may thus be decanted until the rose is close down to the precipitate; but care should be taken at this stage not to push the process too far, lest the filter should become clogged by the adhesion of solid particles, as would be the case, if it comes too near the level of the precipitate. When the safe level has been reached, the arm of the stand is suddenly pushed upwards, while the rose is inverted and supported as above described. The beaker is now filled up with hot water; and, after the precipitate has subsided, the wash water is drawn off as before, and so repeatedly as often as may be necessary. It is important, however, to carefully watch the filter, and every time before immersing the rose to see that the paper is moist and firmly adhering to the perforated plate. It is further essential that the suction should not be for a moment interrupted while the filter is immersed. This condition is secured by the simple rubber joint we have described; for, while when the rose is inverted the connection with the bottle is closed, the moment it is turned down the connection is opened, and the filter begins to draw. If, however, by any accident the filter should slip, the operator when on his guard can avoid loss of material by quickly opening the nipper tap, and relieving the pressure until the rose can be withdrawn and washed out. The filter can then be fished out with a glass rod, washed off and replaced. A good strong filter will bear quite rough treatment; and, if in the process it becomes clogged, it can be taken off when the rose is inverted, and the adhering precipitate washed back into the beaker. When replaced, the paper thus cleansed often filters as rapidly as before. If, as is sometimes the case, the paper becomes hopelessly clogged, no great loss of accuracy is suffered by using a second or even a third filter. Of course, they must all be dried, and weighed either with the precipitate or apart, as most convenient.

The precipitate, having been thus washed, is next to be transferred to the crucible in which it is to be weighed; and, to hold five grammes

of precipitated antimonious sulphide, we shall require a crucible having a capacity of 250 cubic centimetres. As much of the water as can readily be decanted from the precipitate is first poured into the crucible and drawn off with the filter, and then the precipitate is washed in with as little additional water as possible. Now the filter is plunged into the semi-fluid mass, and must not afterwards be removed until the process is completed. The rose ought not even to be raised however slightly, although additional material may be poured in around it. As the mass contracts in the crucible, the filter must be made to follow, always keeping it immersed; and during this time the precipitate which has collected around the platinum rose may be washed down by a stream from a wash bottle. In this way the greater part of the water can be removed, leaving the precipitate nearly as compact as it is left on a common filter, when dried by Bunsen's pump. When the precipitate is in this condition, the pressure is relieved by opening the nipper tap, and the rose raised, which leaves the filter behind. If any of the precipitate has clung to the platinum, this must now be washed into the crucible with a few drops of water, the rose and tube having first been detached from the connector for the purpose. It only now remains to dry the precipitate with the little filter, and weigh it. If it is important to dry the precipitate at a temperature above 150° C., or even to ignite it, the mass should first be thoroughly dried at 100°. The little disk of paper can then be removed and weighed separately, while the rest of the mass is heated to a higher temperature. The amount of material which remains adhering to the paper under these circumstances is exceedingly small, not usually exceeding a few milligrammes; and allowance can be made for it in the final result, without sensible error.

Like other analytical processes, this method has its limits; and any attempt to extend it beyond the sphere of its usefulness will lead to unsatisfactory results. It is of no use for filtering turbid liquids, since the small filters are rapidly clogged, and the process becomes proportionally slow. Whenever, however, a precipitate settles clearly, this method enables us to wash, collect, and weigh very large quantities of precipitates in a very short time with wonderful accuracy. We have used it chiefly to determine sulphide of antimony and chloride bromide or iodide of silver; and the results of the following analyses, extracted from our forthcoming paper on the Atomic Weights of Antimony, will show how great accuracy can be attained with it: —

SYNTHESIS OF SULPHIDE OF ANTIMONY.

Weight in Grammes of Sb taken.	Weight of Sb_2S_3 dried at 180° C.	Per cent of S in same.
2.1439	3.0025	28.58
2.3417	3.2792	28.59
2.2182	3.1061	28.59

ANALYSIS OF ANTIMONIOUS CHLORIDE.

Weight in Grammes of $Sb\,Cl_3$ taken.	Weight of AgCl obtained.	Per cent of Chlorine
2.0300	3.8282	46.652
1.3686	2.5813	46.659
1.8638	3.5146	46.651

ANALYSIS OF ANTIMONIOUS BROMIDE.

Weight in Grammes of $Sb\,Br_3$ taken.	Weight of Ag Br obtained.	Per cent of Bromine.
1.2124	1.8991	66.655
0.9417	1.4749	66.647

These analyses exhibit a fair sample of the results which can easily be obtained with this method. In order to assure ourselves that the weight of the small paper disks remained constant, we have repeatedly dissolved off the small amount of adhering precipitate, and after washing and drying reweighed the disks at the completion of the analysis. Even with the larger disks there was in no case any material change in the weight, and in most cases no alteration whatever could be detected with a balance turning readily with $\frac{1}{10}$ of a milligramme.

The method of collecting precipitates here described, which, as we have shown, is so useful where considerable quantities are to be estimated, is equally applicable to very small amounts. When the quantity of the precipitate does not exceed a few milligrammes, the whole becomes fastened by the suction to the surface of the paper. There is then, of course, no need of a crucible in the process. The filter, having been dried in a watch glass, is weighed by itself, and a result of very great accuracy is reached with great rapidity. We have in this way frequently estimated minute quantities of baric sulphate and argentic chloride, whose weight proved to be only a fraction of a milligramme.

Although the apparatus here described and figured was invented independently by myself in order to overcome difficulties, already stated, which I met with in the course of my investigations, yet in its main features I was anticipated by Professor H. Carmichael, now of Bowdoin College; and I had the misfortune not to have my attention called to his paper on the subject — dated at Göttingen, 1870, and published in the Zeitschrift für Chemie, neue Folge, Band VI., 481 — until long after my own apparatus had been perfected. But although Professor Carmichael and myself started from the same fundamental idea, yet we have worked this idea out in very different forms, and with very different purposes in view. While therefore I would acknowledge most fully Professor Carmichael's priority, I have thought it best to publish this paper with the sole object of adding to his previous work the results of my own experience, and with the hope that I may thus aid in introducing into analytical laboratories what I believe to be the most important improvement in analytical chemistry which has been made since the invention of the Bunsen pump.

Chemical Laboratory of Harvard College, 1876.

X.

CONTRIBUTIONS FROM PHYSICAL LABORATORY OF HARVARD COLLEGE.

No. XII.—ON VORTEX RINGS IN LIQUIDS.

By John Trowbridge.

Presented, March 14, 1877.

It has often been observed by chemists that a drop of colored liquid falling from a burette into a liquid of a different specific gravity, in which it can diffuse, assumes the form of a ring. Vortex motion, by the researches of Helmholtz, Thomson, Rankine, and Maxwell, is now attracting so much attention, that I have thought that a study of the general equations of motion of matter in connection with a study of these rings would contribute to our knowledge of vortex movement.

Prof. W. B. Rogers published in "The American Journal of Arts and Sciences," Vol. XXVI., 1858, a paper on smoke rings and liquid rings, and described several methods of studying them. In Professor Tait's "Recent Advances in Physical Science," a method of forming smoke rings is given. The apparatus consists merely of a large box closed at one end by a thin sheet of india rubber, or with a tightly stretched towel, and having a circular opening of six or eight inches in diameter at the other. Clouds of sal-ammoniac vapor are generated inside the box, and rings are expelled from the circular opening by a blow upon the rubber or towel. Sir William Thomson suggests that two such boxes placed so that the rings may impinge on each other at any angle would form a useful apparatus for studying the behavior of such rings towards each other. At the conclusion of this paper, several methods of studying liquid rings will be described. When a drop of liquid falls from a short distance into a liquid of less density, in which it cannot diffuse, the conditions of its motion just after the instant of its striking the surface of the liquid of less density are indicated by the general equations of heterogeneous strains.* "For

* Thomson and Tait's Natural Philosophy.

each particle we have the component velocities u, v, w, parallel to the fixed axes OX, OY, OZ. These have the following expressions:—

$$\text{Eq. (1)}: \quad u = \frac{d\alpha}{dt}, \qquad v = \frac{d\beta}{dt}, \qquad w = \frac{d\gamma}{dt};$$

x, y, z, t being independent variables, and α, β, γ, functions of them. If the disturbed condition is so related to the initial condition that every portion of the body can pass from its initial to its disturbed position and strain, by a translation and a strain without rotation, — *i.e.*, if the three principal axes of the strain at any point are lines of the substance which retain their parallelism, — we must have, —

$$\text{Eq. (2)}: \quad \frac{d\beta}{dz} = \frac{d\gamma}{dy}, \qquad \frac{d\gamma}{dx} = \frac{d\alpha}{dz}, \qquad \frac{d\alpha}{dy} = \frac{d\beta}{dx};$$

and, if these equations are fulfilled, the strain is now rotational, as specified." But these equations express that $\alpha\, dx + \beta\, dy + \gamma\, dz$, is the differential of a function of three independent variables; and therefore, in order that there may be no rotation, a strain potential must exist. The forces which solicit the particles of the drop when it rests upon the liquid of less density in which it cannot diffuse are evidently their mutual attraction, a force arising from the superficial tension of the liquid, and one arising from gravitation. It is evident, from a consideration of these forces, that, after the drop has suffered a strain at the surface, every portion of the drop cannot pass from its initial position to the next following by a translation and a strain without rotation. For the drop tends to return from a shape approaching an oblate spheroid to that of a sphere. Equations (2) do not hold, and a strain potential does not exist, and therefore this drop must rotate. This rotation is not in general of the ring form. If, on the other hand, the drop of liquid can diffuse itself in the liquid through which it falls, each particle with the velocity u, v, w, is solicited at the moment of impact by a superficial tension, by the force of gravitation, and by a force arising from the rate of diffusion. In this case, there is no tendency of the body to reassume the spheroidal form in its passage through the liquid. On the other hand, to assume that each particle in the next state of the drop very near that which it assumes on striking the free surface of the liquid of less density, is translated without rotation, is to assume that each particle is compelled to move in restrained limits, which do not exist. For the components X^1, Y^1, Z^1, of the attraction, which tend to make the non-diffusible drop reassume its spherical form, we have in the case of the diffusible the components

$X, Y, Z,$ of an external force arising from the superficial tension of the liquid, and the impulse given to the drop.

If we follow the notation of Poisson * and Helmholtz,† we shall have for the general equations of internal motion of a liquid: —

$$\left.\begin{aligned} X - \frac{1}{h}\frac{dp}{dx} &= \frac{du}{dt} + u\frac{du}{dx} + v\frac{du}{dy} + w\frac{du}{dz} \\ Y - \frac{1}{h}\frac{dp}{dy} &= \frac{dv}{dt} + u\frac{dv}{dx} + v\frac{du}{dy} + w\frac{du}{dz} \\ Z - \frac{1}{h}\frac{dp}{dz} &= \frac{dw}{dt} + u\frac{dw}{dx} + v\frac{dw}{dy} + w\frac{dw}{dz} \end{aligned}\right\} 3$$

$$\frac{dh}{dt} + u\frac{dh}{dx} + v\frac{dh}{dy} + w\frac{dh}{dz} = \frac{\delta h}{\delta t} \quad (4)$$

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = o \quad (5)$$

In which p is the pressure in a liquid at the point x, y, z; $X, Y, Z,$ are the components of the external forces acting on a unit of mass; and h is the density. When the variation of h is infinitely small, we have Eq. (5). The forces $X, Y, Z,$ are considered to have a potential V. So that

$$X = \frac{dV}{dx}, \qquad Y = \frac{dV}{dy}, \qquad Z = \frac{dV}{dz} \quad \text{Eq. (6)}$$

and the velocities $u, v, w,$ a velocity potential φ. So that

$$u = \frac{d\phi}{dx}, \qquad v = \frac{d\phi}{dy}, \qquad w = \frac{d\phi}{dz} \quad \text{Eq. (7)}$$

or, $$udx + vdy + wdz = d\varphi,$$

and φ satisfying the equation

$$\frac{d^2\phi}{dx^2} + \frac{d^2\phi}{dy^2} + \frac{d^2\phi}{dz^2} = o$$

which is what equation (5) becomes under the conditions expressed above. We must therefore have

$$\frac{du}{dy} = \frac{dv}{dx}, \qquad \frac{dv}{dz} = \frac{dw}{dy}, \qquad \frac{dw}{dx} = \frac{du}{dz} \quad \text{Eq. (8)}$$

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* Traité de Mechanique.

† Crelle's Journ., LV., 1858.

equations similar to the equations expressing a strain potential. Helmholtz has shown that in the case of rotation of a fluid element, Eqs. (8) become

$$\left.\begin{aligned} \frac{dv}{dz} - \frac{dw}{dy} &= 2\xi \\ \frac{dw}{dx} - \frac{du}{dz} &= 2\gamma \\ \frac{du}{dy} - \frac{dv}{dx} &= 2\zeta \end{aligned}\right\} \text{Eq. 9}$$

and therefore "the existence of a velocity potential is inconsistent with the existence of rotation of the fluid element." We have seen from the equations of strain that the existence of a strain potential is inconsistent with the rotation of a material particle. Let us now see if vortex movement can arise in a liquid from variation of density and pressure. Following Helmholtz's notation, we have, if ψ is a function of x, y, z, t,

$$\frac{\delta\psi}{\delta t} = \frac{d\psi}{dt} + u\frac{d\psi}{dx} + v\frac{d\psi}{dy} + w\frac{d\psi}{dz} \quad \text{Eq. (10)}$$

Calling ξ, γ, ζ, the components of the angular velocity, we can obtain their variations by substituting them in succession in Eq. (10). If we eliminate X, Y, Z, from Eqs. (3) by the help of Eqs. (6), supposing that h and p are functions of x, y, z, t, we obtain, introducing the values of ξ, γ, ζ, from Eqs. (9): —

$$\text{Eq. (11)} \quad \frac{\delta\xi}{\delta t} = -\xi\left(\frac{dv}{dy} + \frac{dw}{dz}\right) + \gamma\frac{dv}{dx} + \zeta\frac{dw}{dx} + \frac{1}{2h^2}\left(\frac{dh}{dz}\cdot\frac{dp}{dy} - \frac{dh}{dy}\,\frac{dp}{dz}\right)$$

and similar expressions for the variations of γ and ζ. If the variation of h is infinitely small, we obtain by the aid of Eq. (5): —

$$\frac{\delta\xi}{\delta t} = \xi\frac{du}{dx} + \gamma\frac{dv}{dx} + \zeta\frac{dw}{dx}$$

If it is not infinitely small, we have the term

$$\frac{1}{2h^2}\left(\frac{dh}{dz}\,\frac{dp}{dy} - \frac{dh}{dy}\,\frac{dp}{dz}\right)$$

which is independent of ξ, γ, ζ, and depends upon the variation of h and p. This term enters into the expressions for the variations in the angular velocities; and shows, therefore, that a vortex movement can arise in a process of diffusion by a variation in density and pressure, without the aid of initial angular velocities. This condition can be

shown experimentally by dropping a somewhat dense solution of one of the aniline colors into a mixture of glycerine and water. The original ring, after ceasing to move downward in the mixture, breaks up gradually into segments, which slowly in their turn assume the ring form. A mixture of water and glycerine is not necessary: peculiar cusp-like figures indicating the first stage of vortical movement can be seen whenever a thin stratum of one liquid slowly diffuses itself through another liquid of different density.

By a consideration of the equations —

$$\varepsilon\,\xi + (u_1 - u)dt = \varepsilon\left(\xi + \frac{\delta\xi}{\delta t}\,dt\right)$$

$$\varepsilon\,\gamma + (v_1 - v)dt = \varepsilon\left(\gamma + \frac{\delta\gamma}{\delta t}\,dt\right)$$

$$\varepsilon\,\zeta + (w_1 - w)dt = \varepsilon\left(\zeta + \frac{\delta\zeta}{\delta t}\,dt\right)$$

given by Helmholtz, from which he draws the conclusion that "each vortex line remains continually composed of the same elements of fluid, and swims forward with them in the fluid," we see, on introducing the new expressions which we have found for $\frac{\delta\xi}{\delta t}$, &c., Eq. (11), that we approach nearer and nearer to this theoretical conclusion when the variations of h are smaller and smaller. Obviously, we should then obtain the most perfect rings when the drop and the liquid in which the motion takes place are composed of the same liquid. And, *therefore, a drop of water falling into water must form a more perfect ring than that formed by a drop of any colored liquid of greater density than water.*

The formation of these liquid rings is as fascinating and as simple an occupation as blowing soap-bubbles. All liquids falling from such a height that the surface of the liquid is not too much disturbed to enable the drop to be acted upon symmetrically by the forces at the free surface will form rings, if too great differences of density do not exist, and if the drop can diffuse in the liquid. The preceding mathematical discussion, as we have seen, shows us that a drop of pure water on striking the same element under the above conditions must necessarily assume the ring shape. This can be shown experimentally by covering the free surface of the water with a fine powder, or with matter in a fine state of subdivision. I have found that an alcoholic tincture of ginger, which gives on the surface of water a milky liquid consisting of particles in a fine state of subdivision, answers the purpose

very well. Fine particles will be carried down by the drop, and will be seen to rotate in a vortex ring far below the surface. This fact can be stated, also, by the employment of any of the aniline colors which are solvent in water, the falling drop consisting of a colored solution whose specific gravity does not differ sensibly from that of water. The method that I have employed to produce the rings consists merely of a small glass tube, slightly smaller at one end than the other. A bit of cotton is wedged in nearer the larger end, over which a piece of flexible rubber tubing is slipped. With the aid of the mouth, one can fill this tube with liquid and eject it in drops at pleasure. The same apparatus enables us to form the rings beneath the surface of the liquid. With a tube bent horizontally, one can send the rings through a liquid in any desired direction; and, by means of a three-way glass joint and a small india-rubber bag, one can send forth, by the same impulse, two rings whose paths make any desired angle with each other. By partly immersing the glass tubes connected with the three-way tube in the free surface of the liquid, and covering the surface of the water with fine powder, one can study the mutual behavior of half-vortex rings. A simpler method is to illuminate, by means of a gas-light, the bottom of a flat, white porcelain dish filled with water, and to observe the shadows of the half-vortex rings on the bottom of the dish formed by the movement of two spatulæ along the surface. It can be readily seen, by this simple method, that a half-vortex ring moving near another in a parallel path and with a less velocity tends to follow in the path of the first; and that two equal half-vortex rings moving in opposite directions along the same path separate into two vortices which move at right angles to the path of the original vortices. We can conclude, also, from this general discussion, that, whenever a mass of vapor of greater density than the surrounding air is suddenly formed in the higher regions of the atmosphere, it tends to descend through it in a vortex ring.

The results of the preceding discussion are as follows: —

1. An analogy between the strain potential and the velocity potential is indicated.

2. It is shown that the formation of liquid rings is a necessary result of the fundamental equations of strains and those of hydrodynamics; and that they constitute a general and not a special phenomenon. A drop of water falling into water from a suitable height must assume a ring shape.

3. Vortices can and do arise in certain processes of diffusion.

4. Simple methods of studying vortex motion in liquids are given.

XI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD COLLEGE.

NO. XIV. — ON A NEW METHOD OF COMPARING THE ELECTROMOTIVE FORCES OF TWO BATTERIES AND MEASURING THEIR INTERNAL RESISTANCE.

By B. O. Peirce, Jr.

Presented, March 14, 1877.

The relative strengths of two currents which give rise to different deflections of a galvanometer needle are not easily compared, and therefore it has been the aim of physicists in making electric measurements to choose such methods as require the current through the galvanometer to be made either zero, or else equal in two given cases. The method of measuring resistances by Wheatstone's Bridge is an example of a "nul" method. Mance's and Thomson's methods of measuring the resistances of batteries are examples of the class which require equal deflections.

Poggendorff's method of comparing the electromotive forces of two batteries is the only accurate method which belongs under either of these heads.

I have found that very accurate results can be obtained in the following way: —

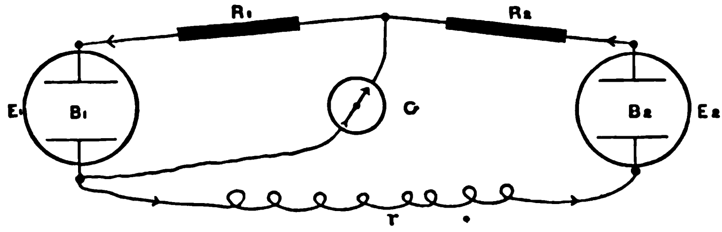

Fig. 1.

The batteries to be measured are arranged as in the figure, with their electromotive forces conspiring. r is any small resistance. R_1

and R_2 are resistances which may be varied until no current passes through the galvanometer. When the current through the galvanometer is nothing, the ratio of the electromotive forces of the two batteries is very easily found. Let E_1 and E_2 be the electromotive forces of the two batteries, and B_1 and B_2 their internal resistances.

Kirchoff's Second Law, when applied to the closed figure embracing the resistance B_1, R_1, G, gives,

$$E_1 = (B_1 + R_1)C \qquad (1)$$

where C is the current traversing the circuit.

The same law when applied to the closed figure r, B_2, R_2, G, gives

$$E_2 = (r + B_2 + R_2)C \qquad (2)$$

Dividing (1) by (2)

$$\frac{E_1}{E_2} = \frac{B_1 + R_1}{r + B_2 + R_2} \qquad (3)$$

In order to use this formula, we must know the values of B_1 and B_2. These may be determined thus: Give to R_2 a little different value, and vary R_1 until there is again no current going through the galvanometer. Repeat this operation with still a different value of R_2, and there will be three different values of the ratio of the electromotive forces, which will give three equations to determine B_1, B_2, and $\frac{E_1}{E_2}$. R_1 and R_2 are most conveniently made large; and in this case, if extreme accuracy is not needed, we may neglect B_1 and B_2 compared with R_1 and R_2.

It is, of course, not necessary to have any resistance corresponding to r; but as it is often possible to get quite accurate results by making R_1 and R_2 small resistances, and then varying r by means of a rheostat until no current traverses the galvanometer, a resistance r is inserted in the figure.

The chief advantages of this method are: —

1st, its great accuracy.

2d, that the current through the galvanometer is made zero.

3d, that the circuit does not have to be broken during the comparison.

4th, that the resistances of the two batteries are very readily obtained without altering any of the adjustments, if their electromotive forces are constant.

The greatest disadvantage in this arrangement is that a large

current passes through the resistance coils. The current through the coils may be reduced by connecting, through a shunt, the battery-poles which are already connected by the resistance coils, and in this way one can avoid all risk of injuriously heating the fine wire.

The use of the shunt makes the formula which determines the ratio of the electromotive force of the two batteries a little more complex, but the mechanical work of the comparison is not altered.

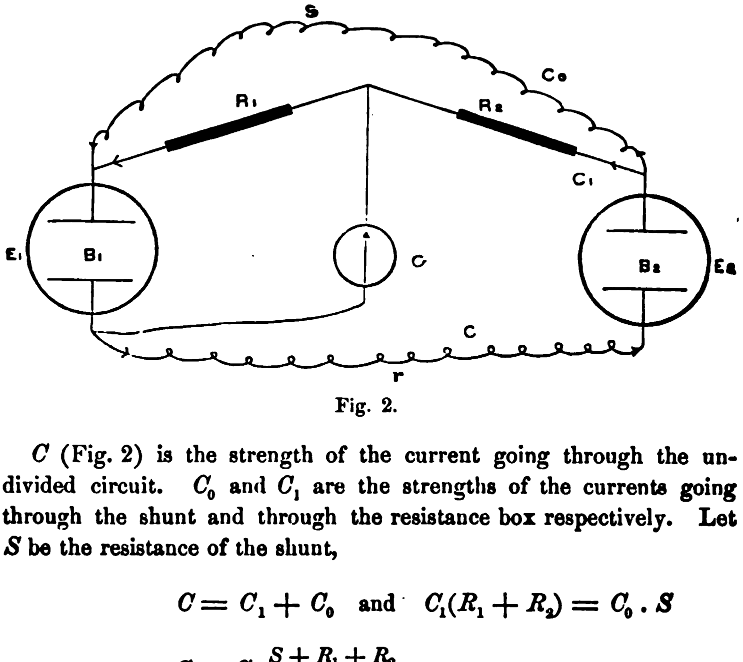

Fig. 2.

C (Fig. 2) is the strength of the current going through the undivided circuit. C_0 and C_1 are the strengths of the currents going through the shunt and through the resistance box respectively. Let S be the resistance of the shunt,

$$C = C_1 + C_0 \quad \text{and} \quad C_1(R_1 + R_2) = C_0 \, . \, S$$

$$\therefore \; C = C_1 \frac{S + R_1 + R_2}{S}$$

$$C_1 = \frac{CS}{S + R_1 + R_2}$$

Kirchoff's Second Law gives, when applied to the closed figures B_1, R_1, and G, and r, B_2, R_2, and G,

$$E_1 = B_1 C + \frac{R_1 SC}{S + R_1 + R_2} \tag{1}$$

$$E_2 = (r + B_2) C + \frac{R_2 SC}{S + R_1 + R_2} \tag{2}$$

Dividing (1) by (2)

$$\frac{E_1}{E_2} = \frac{B_1(S + R_1 + R_2) + R_1 S}{(r + B_2)(S + R_1 + R_2) + R_2 S} \qquad (3)$$

which is the formula required.

NO. XV. — ON A NEW METHOD OF MEASURING THE RESISTANCE OF A GALVANIC BATTERY.

By B. O. Peirce, Jr.

Presented, March 14, 1877.

Of the many known methods of measuring the resistance of a galvanic battery, only two, those of Mance and Thomson, are found to give accurate results. A third method, which seems to work well in practice, is this: —

A known resistance (r), a galvanometer of known resistance (G), and the battery whose resistance is to be measured, are joined up in a simple circuit. The battery is shunted, and the deflection of the galvanometer needle is noted. This shunt is now removed, and the galvanometer is shunted, so that it gives the same deflection as before. A knowledge of the ratio of the resistances of the shunts gives the resistance of the battery by means of a simple formula. Let E be the electromotive force of the battery, and B its resistance, and let S and σ be the resistances of the shunts. In the expressions that follow, C_g, C_s, and C_σ denote currents passing through the galvanometer and the two shunts respectively.

When the battery is shunted, the whole current in the circuit is

$$C = \frac{E}{\dfrac{1}{\dfrac{1}{S} + \dfrac{1}{r + G}} + B} = \frac{E(S + r + G)}{S(r + G) + B(S + r + G)} \qquad (1)$$

Kirchoff's Laws give

$$C = C_g + C_s \quad \text{and} \quad C_s \,.\, S = C_g(r + G)$$

therefore

$$C = C_g \frac{(S + r + G)}{S} \qquad (2)$$

Equating the second members of (1) and (2)

$$ES = C_G\left\{S(r + G) + B(S + r + G)\right\} \qquad (3)$$

When the battery shunt is removed, and a shunt put across the terminals of the galvanometer, the whole current traversing the circuit is

$$C' = \frac{E}{\dfrac{1}{\dfrac{1}{\sigma} + \dfrac{1}{G}} + r + B} = \frac{E(\sigma + G)}{G\sigma + (r + B)(G + \sigma)} \qquad (4)$$

Kirchoff's Laws give

$$C' = C_G + C_\sigma \quad \text{and} \quad C_\sigma \cdot \sigma = C_G \cdot G$$

therefore

$$C' = C_G\left(\frac{\sigma + G}{\sigma}\right) \qquad (5)$$

Equating the second members of (4) and (5)

$$E\sigma = C_G\left\{G\sigma + (r + B)(G + \sigma)\right\} \qquad (6)$$

Dividing (3) by (6) and cancelling, we have, since the current passing through the galvanometer is the same in both cases,

$$[G\sigma + (r + B)(G + \sigma)]S = [S(r + G) + B(S + r + G)]\sigma$$

or if

$$\delta = \frac{\sigma}{S}$$

$$B = \frac{rG}{(r + G)\delta - G}.$$

In practice, the terminals of r are connected to the galvanometer and to the battery respectively by binding-screws with three wire holes in each. One terminal of a Wheatstone's Rheostat is permanently fastened to one pole of the battery, and the other terminal is connected, first with the binding-screw on one side of r, and then with that on the other side. The handle of the Rheostat is to be turned until the galvanometer needle gives the same deflection in the second

case as in the first, and the ratio of the lengths of the shunt are taken to represent the ratio of their resistances.

With a piece of uncovered copper wire, not more than two metres long, and a resistance r equal to only twenty-four one hundredths of an ohm, I have obtained results which are quite as good as those obtained with a box of resistance coil, using Thomson's method.

r should be a small resistance of not over five ohms for a long-coil galvanometer, and not over three ohms for a short-coil galvanometer. This method offers some advantages over that of Thomson, but it is not generally as good as the method due to Mance.

XII.

NOTE ON THE DETERMINATION OF THE LAW OF PROPAGATION OF HEAT IN THE INTERIOR OF A SOLID BODY.

By B. O. Peirce, Jr.

Presented April 11th, 1877.

Newton's experiments upon the amount of heat communicated from a body A to a neighboring body B, at a lower temperature than A, led him to think that this amount was directly proportional to the difference of temperature between the two bodies. In 1805, Biot, assuming that Newton's results were reliable, conceived that the same law must hold for the communication of heat between two neighboring molecules in the interior of a solid body, and he compared the observed temperatures at different points of a long bar heated at one end with the temperatures calculated on the assumption that the flux of heat in the direction x is represented by

$$-\varkappa \frac{dv}{dx}$$

where $\varkappa$ is constant for the same body and v is the temperature of the point under consideration. Fourier — whose "Théorie de la Chaleur" was written in 1811, but not published until 1822 — followed Biot in assuming

$$-\varkappa \frac{dv}{dx}$$

to represent the flux of heat in the inside of a body, and

$$-h \frac{dv}{dx}$$

the radiation at its surface, where $\varkappa$ and h are different constants which he calls respectively the "conducibilité propre" and "conducibilité relative à l'air atmosphérique." Just before Fourier's work was published, MM. Dulong and Petit showed that the amount of heat communicated from one body to another depends not only upon the

difference of their temperatures, but also upon the absolute temperatures of each. Poisson published, in 1835, his "Théorie de la Chaleur," in which he assumed that the expression which Dulong and Petit had given for the loss of heat from radiation also represents the passage of the heat from molecule to molecule in the interior of the body. Libri, shortly before Poisson's book was published, presented to the Academy of Sciences a paper in which he assumed that Fourier and Biot were correct in their hypothesis that the internal flux of heat could be written

$$-\kappa \frac{dv}{dx},$$

but that the law of extra radiation was that stated by Dulong and Petit. In 1837, Kelland published his "Theory of Heat." He applied Libri's hypotheses to the problem of determining the final distribution of heat in a ring, and showed that the solution thus arrived at was not very different from that which Fourier had determined. In other respects, Kelland simply gave Fourier's work with corrections, as his object was to furnish a book for students. In 1841, Professor Kelland made a report to the British Association for the Advancement of Science "On the Present State of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat."

In this report, Kelland says that, although objections might be made to the particular assumptions of Fourier, Libri, and Poisson, it is very probable that the flux of heat in the interior of a body may be written

$$-c \frac{df(v)}{dx},$$

where c is a constant depending upon the body and $f(v)$ is some undetermined function of the temperature. Kelland assumed a particular value for $f(v)$, and compared the temperatures calculated from the different hypotheses of Fourier, Libri, Poisson, and himself, with the corresponding temperatures observed by Biot in his experiments upon long bars. This comparison does not give the preference to any one of the different assumptions. Since 1841, nothing of any importance has been done, so far as I know, in the general theory of heat conduction. Lamè, whose "Théorie de la Chaleur" was published in 1862, follows Fourier in his hypotheses, and those writers who, like Sir William Thomson, have had occasion to discuss practical questions about the cooling of bodies, have also made the same assumptions,

since the error thus introduced into their calculations is necessarily less than those arising from errors in observing the phenomena.

Dulong and Petit's experiments showed that Fourier's assumption with regard to the flux of heat at the surface of a body due to radiation was wrong, and Principal Forbes's experiments upon heated metallic bars showed that, in order to write the flux of heat in the interior of a body

$$-\varkappa \frac{dv}{dx},$$

$\varkappa$ must be regarded as a function of the temperature. Forbes's experiments evidently offer no objection to Kelland's hypothesis, for

$$-\varphi(v)\frac{dv}{dx} \quad \text{and} \quad -c\frac{df(v)}{dx}$$

are equivalent expressions, if

$$\varphi(v) = cf'(v).$$

The first step in determining the form of the function f is made by showing that it must satisfy a differential equation which when the heated body is at its final state, reduces to Laplace's Equation.

Consider the element of volume $dxdydz$, which has one of its angles at the point (x, y, z) and its diagonally opposite angle at $(x + dx, y + dy, z + dz)$. During the instant dt, the flux of heat across that face of the element which contains the point (x, y, z) and is parallel to the coördinate plane xy, is

$$F(v, z) = -c\frac{df(v)}{dz}dxdydt.$$

The amount of heat which flows out at the opposite face of the element is obtained by developing $F(v, z)$ by Taylor's Theorem:

$$F(v + dv, z + dz) = -c\frac{df(v)}{dz}dxdydt - c\frac{d^2f(v)}{dz^2}dxdydzdt.$$

The flux across the second face is less than the flux across the first face by

$$c\frac{d^2f(v)}{dz^2}dxdydzdt.$$

Considering each of the other pairs of opposite faces, it is evident that in the instant dt a quantity of heat equal to

$$cdxdydz\left(\frac{d^2f(v)}{dx^2} + \frac{d^2f(v)}{dy^2} + \frac{d^2f(v)}{dz^2}\right)dt$$

have been added to the element. Let Q be the total amount of heat in the molecule, then

$$d_t Q = - c dx dy dz \left(\frac{d^2 f(v)}{dx^2} + \frac{d^2 f(v)}{dy^2} + \frac{d^2 f(v)}{dz^2} \right) dt$$

If Laplace's Operator is written "$-\nabla^2$,"

$$\frac{d_t Q}{dt} = - c \nabla^2 f(v)\, dx dy dz.$$

Let s be the specific heat of the body which Dulong and Petit have shown to be a function of the temperature, and let $s = \Psi'(v)$, then

$$d_t Q = d_t v \,.\, \Psi' s \,.\, dx dy dz,$$

$$\Psi'(v) \,.\, \frac{d_t v}{dt} = - c \nabla^2 f(v)$$

If $\qquad r^2 = x^2 + y^2 \qquad$ and $\qquad \varphi = \tan^{-1} \frac{y}{x}$

$$- \nabla^2 f(v) = \frac{d^2 f(r)}{dr^2} + \frac{d^2 f(r)}{r^2 \,.\, d\phi^2} + \frac{d f(v)}{r \,.\, dr} + \frac{d^2 f v}{dz^2}$$

$$\therefore \Psi'(v) \frac{d_t v}{dt} = + c \left(\frac{d^2}{dr^2} + \frac{d}{r \,.\, dr} + \frac{d^2}{r^2 d\phi^2} + \frac{d^2}{dz^2} \right) f(v)$$

If the body has reached its final state, the element loses as much heat in any given time as it gains, so that $f(v)$ must satisfy Laplace's Equation, or

$$\nabla^2 f(v) = 0.$$

Consider a thin plate of metal of practically infinite extent, and of which all points are at a uniform temperature. Let this plate be laid upon and covered with some perfectly non-conducting material, so that there can be no flux of heat perpendicular to the plane of the plate, and let a single point be heated by means of a copper wire pushed through the non-conducting material upon which the plate lies.

There will be a flux of heat from the heated point in all directions in the plane of the plate; and, if the plate is homogeneous, the flux will be the same in all azimuths.

After the plate has reached its final state, the amount of heat added to each element of the plate will be the same that flows out of it, and $dQ = 0$. If the plate lies in the coördinate plane xy, there will be no flux in the direction of the axis of z, and hence

$$\frac{d^2 f(v)}{dz^2} = 0;$$

and, if the plate is homogeneous,

$$\frac{d^2 fv}{d\phi^2} = 0.$$

Therefore $f(v)$ must be a solution of the differential equation

$$\frac{d^2 f(v)}{dr^2} + \frac{1}{r} \cdot \frac{df(v)}{dr} = 0$$

or $$f(v) = A + B \log r,$$

and the flux $$= -c \frac{df(v)}{dr} = -\frac{cB}{r}$$

Consider a second plate of metal in every way like the first, only that it is heated at two points by means of a Y shaped piece of copper which is itself heated at its stem. The two arms of the Y are pushed through the non-conducting material and are of equal lengths, so that the two points shall be equally heated.

If r_1 and r_2 are the distances of any point from the two heated points, it is evident from the theory of conjugate functions that

$$f(v) = A' + B' \log r_1 r_2$$

$f(v)$ is constant along any curve of the system $[r_1 r_2 = \text{const.}]$ If a is the distance of the heated points from each other, the equation of the system of curves for any one of which $f(v)$ is constant may be written

$$(x^2 + y^2)\left((x - a)^2 + y^2\right) = k.$$

Before the plate is imbedded in the non-conducting material, let it be covered with a thin layer of a mixture of paraffine, rosin, and wax, and after it has been heated long enough to have sensibly reached its final state let the source of heat be removed; then, if there is a clean line of demarcation between the wax that has been melted and that which has not, the form of one of the isothermals can be studied at leisure. Wherever $f(v)$ is constant, v must be constant unless $f(v)$ is an equation of an infinitely high degree, which is inadmissible; and conversely, if v is constant along any curve, $f(v)$ must also be constant at all points on that curve. If the isothermal traced by the melted wax is a curve whose equation is $r_1 r_2 = c$, it will be safe to assume that the flux of heat in the interior of a body is

$$-c \frac{df(v)}{dx},$$

as Kelland assumed. By use of a suitable arrangement, it would be very easy to use such ranges of temperature as should make the experiment decisive. If the points were unequally heated by accident, the wax curve would not be symmetrical with respect to a line perpendicular to that joining the two heated points. There could be no trouble with lack of homogeneity of the plate, as preliminary experiments show that from a single heated point the curve is perfectly symmetrical and distinct, with a probable error in finding the line of demarcation practically insensible. I am indebted to Professor Gibbs for the suggestion that the New Hampshire Infusorial Earth might be advantageously used as an almost perfect non-conductor of heat.

Whatever might be the result of a series of experiments like those referred to above, it is evident, from the differential equation, that Fourier's solution cannot be a correct one. If the uniform temperature of the plate were taken as the zero of the scale, the temperature of any point in the plate due to the two heated points would be the sum of the temperatures that would be given to the same point if each heated point acted alone. On this hypothesis, it would be very easy to find a point in the plate so situated that, when the plate had reached its final state, the point would have a temperature nearly double that which either of the heated points have, which is manifestly absurd. It does not appear that writers upon this subject have noticed this fact.

If experiment shows, as it probably will, that the propagation of heat in the interior of a solid is determined by the expression

$$-c\,\frac{df(v)}{dx},$$

it will not be hard to determine $f(v)$ experimentally. The infusorial earth, it is believed, will prevent any sensible loss of heat from conduction or radiation, so that the flow of heat in the plate will be determined solely by the law of internal flux. Let a plate of any metal other than copper be heated at a single point, and after it has reached its final state let the temperatures of the different points of the plate be determined relatively by means of the thermoelectric currents obtained by touching different points of the plate by the copper terminals of a Thomson's Short-Coil Galvanometer. These terminals are to be held by wooden pincers, and pushed through the light infusorial earth so as to explore the points of any line radiating from the point where the heat is applied.

Let r_0, r_1, r_2, r_3, &c., be a series of points in such a line determined by experiment, so that the galvanometer gives the same deflection when one terminal is at r_{n-1} and the other at r_n as it does when the first terminal is at r_1 and the second at r_2. If v is the temperature of all points upon the circle whose radius is r_0, the temperature of all points at a distance from the heated point equal to r_1 will be $(v - \nabla v)$, and all points at a distance of r_n will have a temperature equal to $(v - n\nabla v)$. The temperatures may be determined as a function of r, $[v = \varphi(r)]$ by obtaining the equation of the curve drawn by plotting the temperature as abscissas and the corresponding values of r as ordinates; and the form of the function f may be mathematically obtained from the equation.

$$f\big(\varphi(r)\big) = A' + B' \log r,$$

A' is the value of $f\big(\varphi(1)\big)$.

Kelland unintentionally says that the assumption of

$$-c\,\frac{df(v)}{dx}$$

as the law of flux will only necessitate the writing of $f(v)$ instead of v in Fourier's formulæ. This statement is evidently only true when these formulæ refer to a body which has attained its final state.

Mr. E. B. Lefavour and myself are engaged upon the experimental work laid out in this paper.

HARVARD UNIVERSITY, April 4, 1877.

XIII.

ANTIGENY, OR SEXUAL DIMORPHISM IN BUTTERFLIES.

By Samuel H. Scudder.

Presented, March 14, 1877.

In his work on Selection in relation to sex, Darwin discusses the difference of coloring which frequently distinguishes the sexes of butterflies, and concludes that "the male, as a general rule, is the most beautiful, and departs most from the usual type of coloring of the group to which the species belongs." (op. cit. i. 390.) Of the first proposition there can be no doubt; but, in the second, two distinct elements appear to be confounded: the separation of these is the object of the present communication.

Sexual dimorphism, or antigeny,* as exhibited in butterflies, is of two kinds, — colorational and structural. Colorational antigeny again may be divided into two classes: the first including those cases in which it is partial; the second, those in which it is complete.

As one example of partial antigeny, we may take *Cyaniris pseudargiolus* (Boisd.-LeC.). In the south, a portion of the females of the spring brood have the upper surface of the wings uniformly brown; another portion have the greater part blue, like the male; in the north, all the females are blue. In *Jasoniades Turnus* (Linn.), the males, and in the north all the females, are yellow above, heavily banded with black; in the south, a large proportion of the females have lost the yellow ground, and become wholly black; while others retain the universal ground-tint of the male. The dark female of *Atrytone Zabulon* (Boisd.-LeC.) was for a long while considered a species distinct from the normal female, in which the tawny colors of the male are shared by its mate.

* This term, signifying opposition or diversity of the sexes, is proposed to avoid circumlocution; for there are so many forms of sexual dimorphism requiring specific names, that a compound term for the general phenomenon becomes inconvenient.

These are all cases of melanism, and may be taken as examples of a class; in the first two, perhaps in all, it is only toward the southern part of the insect's range that the melanism appears, and is in accordance with the general rule that melanic antigeny is more common at the south, while its opposite, albinism, is more frequent toward the north.

Albinism, for instance, is a common feature in the northern genus *Eurymus*. In our common *E. Philodice* (God.) and *E. Eurytheme* (Boisd.), many females may be found in which the bright yellow or orange of the upper surface is replaced by a sordid greenish-white; and if we go farther north, or to higher altitudes, we shall find other species, in which the albinism has become complete, affecting all the females.

It is a curious circumstance that, while albinic antigeny finds its most complete expression in high temperate regions, and melanic antigeny prevails toward the tropics, the albinic females of a partially antigenic species never appear in the spring brood, but increase in numbers throughout the hot season; while, at least in the case of the blue butterfly mentioned, the melanic females emerge in early spring, are confined to this brood, and are replaced in warmer weather by the gynandromorphic females; thus, spring apparition appears to be correlated with southern distribution, and summer apparition with northern distribution: these two phenomena appear, in either case, to be directly antagonistic.

Although both albinism and melanism may become complete, partial antigeny, wherever it exists, is confined to the phenomena of melanism and albinism, and does not extend to the more varied forms of complete colorational antigeny, to which reference will now be made.

In the male of *Xanthidia Nicippe* (Cram.), the black bordering band of the wings is sharply defined, and extends across the entire outer margin; in the female, the band is blurred, and stops abruptly before it reaches the lower angle of the front wings, or has half traversed the hind wings. In *Hedone Brettus* (Boisd.-LeC.), the female is very dark-brown, almost black, with two little yellow spots in the middle of the front wings; while the male differs totally, being tawny with indented brown borders and an oblique black dash in the middle of the front wings: at first glance, no one could suppose them identical. In *Semnopsyche Diana* (Cram.), the male is a rich dark-brown with a very broad fulvous margin upon all the wings, marked on the front wings by one or two rows of black spots. The female, on the

other hand, is a rich purple-black, with no trace of fulvous, but with the space where it belongs occupied on the fore wings by three rows of white spots and dashes, and on the hind wings by two belts of blue, broken into spots, one of the belts narrow, the other exceedingly broad. In *Erora læta* (Edw.), the male is wholly brown, with a border of deep blue on a portion of the hind wings; while in the female, the blue has extended so as to cover almost all the hind wings, and even the base of the fore wings. But it is in the Coppers (*Villicantes*) that this phenomenon is most common. Here the females are usually of a fulvous color heavily spotted with black, and particularly noticeable for their conspicuous broad dark border, and a row of spots crossing the wing beyond the middle; while the males are either of some dark-brown shade with a purplish gloss, or of a fiery hue, almost always without any border or spots.

Now in all these cases of colorational antigeny, it is the female, and never the male, which first departs from the normal type of coloring of the group to which the species belongs. Occasionally the feminine peculiarity has been transmitted to the male, and, by this means, a new type of coloration established in the group; but I recall no case where the male alone departs from the general type of coloring peculiar to the group. This is precisely the opposite conclusion to that which Darwin reached. He gives several examples on the authority of Bates, which certainly favor his conclusion, but may, at the same time, be explained from the opposite point of view. He gives other examples from the European blue butterflies, which not only do not support, but even oppose, his general statement.

Take the case of *Semn. Diana*, than which we could hardly find a stronger, since the group (*Dryades*) to which it belongs is remarkably uniform, exhibiting in all its numerous members the same characteristic play of fulvous and black markings. The male of *S. Diana* is indeed very unlike most other fritillaries, but it retains, nevertheless, abundant traces of the same style of ornamentation, and has precisely the same colors, while the female departs widely from the characteristic features of ornamentation, and, in addition, loses every trace of fulvous, so that no one at first glance would recognize it as a member of the group. Take again *Eurymus Philodice* and its allies. In some species, indeed, there are only pale females; but in others all, or most of the females, are yellow or orange, like the males; and any one who knows how yellow and orange tints prevail throughout the group of *Fugacia* will acknowledge that the color of the males is normal. So too with the Blues (*Adolescentes*), which Darwin him-

self quotes: in almost all of them, both males and females are of some shade of blue; in comparatively few, the males are blue and the females brown; in exceedingly few, both sexes are brown; and the very fact that they are familiarly known as "Blues" is a popular recognition of the prevailing color. In the group of Skippers to which *H. Brettus* belongs (*Astyci*), the prevailing colors, at least in the temperate zones, are certainly tawny and black, or brown; the latter, marginal. This is the case with the male of *H. Brettus*, while the female diverges from the type in becoming wholly brown. In *Jasoniades Turnus*, where we sometimes have a black female, it is more difficult to decide what should be considered the normal color, owing to diversity of view upon the relationship of many of the Swallow-tails; but, to judge only from those agreed by all to be most nearly allied to it, there can be no question whatever that the striped character prevails.

It will also be noticed, in this last case and others given, that wherever partial antigeny or dimorphism is confined to one sex, it is always to the female: there seems to be no exception to this rule. In these instances, on my hypothesis, half of the females depart from the type; on Darwin's, half of the females, and all of the males. But if, on Darwin's theory, sometimes one-half, and sometimes three-quarters of a species has diverged from the type, why does it never happen that only one-fourth of the species diverges? This seems to be a very pertinent and damaging inquiry.

The instances given by Darwin, which strongly sustain his view, are drawn from specimens of the South American genus *Epicalia*, found in the rich cabinet of Mr. Bates. The facts, as stated by him, are these: There are twelve species of the genus discussed by him;* of these, nine have gaudy males and plain females; one has plain male and plain female; and two have gaudy males and gaudy females. The plain females, he adds, "resemble each other in their general type of coloration, and likewise resemble both sexes in several allied genera, found in various parts of the world." To examine this case fairly would need a large collection of exotic butterflies. If we confine ourselves to *Epicalia*, we evidently cannot say whether the gaudy or the plain coloring be normal: there would be less variation from the standard on the supposition that the gaudy were the normal type, and in this case it is the female which has departed from the type; but the difference is not enough to form an objection. It is only when we look outside of *Epicalia* that judgment seems to lean toward Darwin's

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* Kirby, in his last general catalogue, gives fifteen.

side; but, from the unfortunate want of material, I cannot fairly discuss this point.

Take, however, another case, which appears to be equally complicated, — our native Coppers (*Villicantes*). We have one species in which both sexes are fiery red marked with black; another where both are fulvous marked with black; others where both sexes are brown; and several where the male is brown, marked with fulvous, and the female fulvous, marked with brown; others where the male is wholly brown, and the female fulvous, spotted with brown; and again others with fiery male, and brown female. We have nearly every possible variation, but the prevalent feature is a dark male, often with more or less metallic reflections, which sometimes increase so as to give the insect a fiery copper hue; and a fulvous, spotted, and margined female. I do not see how we can possibly discover, with any certainty, from within the limits of the group of Coppers, what should be considered the normal type. Nor are we much better off in an examination outside the group: there the prevailing tint is either brown or blue; and I am inclined to think that brown, tending strongly to copper, should be considered the normal type; in which case the males are normal, and the species generally antigenic.

But sexual dimorphism is not confined to color or pattern; there is also structural, as well as colorational, antigeny. This term embraces all those minor features which, in these and other animals, have been classed as accessory or secondary sexual peculiarities. Structural antigeny is always complete, and, in direct opposition to the features we have been discussing, is wholly confined to the males.

In butterflies, structural antigeny is mostly confined to the wings and the legs; occasionally it appears in the antennæ. Sometimes it affects the contour of the wings. One of the most conspicuous cases among our own butterflies is in *Strymon Titus* (Fabr.), where the fore wings of the male have a pointed tip, and the hind wings have the inner angle sharply defined; while in the female both the tip of the fore wings and the inner angle of the hind wings are broadly rounded.

Or it may affect the direction of the veins of the wings. Usually the difference between the sexes is slight, and concerns the point of origin of one or two of the upper branches of the subcostal vein of the fore wings; but occasionally it is very marked, as in many hair-streaks, such as *Thecla Edwardsii* Saund., where the branches of the subcostal vein near the end of the cell are thrown far out of place to accommodate a patch of peculiar crowded scales; this patch itself,

moreover, is a feature of the males alone, and occurs in many hair-streaks where the position of the veins is not altered.

One of the most curious patches of this kind is found in the males of some species of *Eurymus*, although wholly absent from others intimately allied to them. It is a little patch of lustreless scales, which occurs at that part of the base of the hind wings which is always covered by the front wings, so that it is quite concealed from sight. Patches of a different nature also mark the male sex; thus, next the middle of the lower median vein of the hind wing of *Danaida Plexippus* (Linn.), and in some of its allies, we have a heavy thickening of the membrane, conspicuous from its covering of black scales.

In very many males of the larger Skippers (*Hesperides*), the front edge of the fore wing is abnormally expanded, and folded compactly upon the upper face of the wing, so snugly that often it can only be discovered with the lens; moreover the scales within this have turned to white silken floss, which, when the fold is raised, contrast conspicuously with the ordinarily dark surface of this part of the wing. In certain Swallow-tails (*Equites*) also, the inner border of the hind wings is folded back in a similar, though looser, manner; but is so much larger that, when opened, it often exposes a white downy surface as large as the abdomen.

Then again there is much variety of male adornment in special modifications of hairs or scales upon the wings. The patch of the hair-streaks already mentioned is one instance of this; another example is found among the *Dryades*, in a row of long, fulvous, partially erect hairs along the upper edge of the cell of the hind wings; this is accompanied by a curious apparent thickening of the veins in the middle of the fore wing, due altogether to the presence of a multitude of small and densely clustered black scales, crowded against the veins at this point. A faint oblique patch of minute and crowded lustreless scales, accompanied by long silky hairs, is often seen crossing the wings of some of the Satyrids; but this feature finds fullest expression in the *Astyci*, or smaller Skippers, where a large proportion of males have a patch or oblique dash of peculiar scales covering veins and membrane indiscriminately, but usually, and in our native butterflies always, occupying the middle of the front wing, and crossing the median veins obliquely near their base. This dash is variously formed, but the scales which compose it are much larger than the ordinary scales, are black, and frequently partially erect. They may also differ in various parts of the patch itself, and alter its character abruptly; for instance, some comparatively huge and brilliant scales may occupy the

middle line, and be buttressed by a multitude of minute, crowded, lustreless scales; or there may be at one point a sort of whirlpool of large party-colored scales, imbricated, in the most regular fashion, like the normal scales, and, beyond them again, a multitude of the minute, crowded, lustreless scales. These peculiarities, however, must be studied with a glass; the naked eye may indeed discern that the patch differs in different insects, but the general effect in all alike is a variously formed velvety patch or oblique streak of black.

It may be remarked, in passing, that wherever antigeny, colorational or structural, manifests itself in the wings of butterflies, the differences between the sexes almost invariably occur upon the upper surface, and generally upon the front wing only; it occasionally happens that there is a slight difference in the general tone of color on the under surface of both sexes, corresponding to what appears above, as in *Semnopsyche Diana;* but it rarely affects the markings of the wings. The differences upon the upper surface, however, and especially upon the fore wings, are, as we have seen, often conspicuous and very curious. One can scarcely doubt that this is in direct relation with the general absence of all ornamentation from the lower surface of both wings, and usually also from the upper surface of the hind wings, of moths.

Sexual dimorphism in the legs shows itself in the proportional length of the different pairs in the two sexes, in the special development of certain joints, in the appendages, and in the clothing. It appears remarkably in the appendages of the two higher families of butterflies, *Nymphales* and *Rurales*, and especially in the latter family, where the terminal appendages of the fore legs are nearly or quite lost in the males, and are as conspicuous as on the other legs in the female. I have not discovered that the differences in the length of the leg-joints follow any general law, although there are few of our butterflies whose sexes do not vary in this particular; this form of antigeny is also most conspicuous in the *Rurales.* The males of certain *Villicantes* (*Chrysophanus, Epidemia, Heodes, Feniseca*) also present another curious feature in a tumid swelling of the basal joint of the middle and hind tarsi. Finally, the fore legs of the males of *Nymphales* are frequently furnished with a spreading brush of hairs; or, in other butterflies, the thighs and shanks of the middle and hind legs are supplied with curious pencils or fringes of stiff hair, which appear to have the same significance as similar adornments in higher animals.

Darwin supposes that these various male appurtenances, which occur throughout the animal kingdom, have all arisen by natural selection, — that one of rival males being selected as a mate whose outward

charms are greatest. He certainly brings powerful argument and a strong array of facts to support this hypothesis; but what then shall be said of the following illustration of structural antigeny; viz., the presence in many males, but in no females whatever, of scales of the most exquisite beauty and delicacy, scattered among the more common sort, and invisible to the naked eye? Even with the help of the microscope, they can often only be discovered by ruffling the wing, and forcibly extracting them from their concealment; and, so far as we can see, they give to the wing no peculiar character by which it may be distinguished from other wings.

These peculiar scales, or androconia, as they may be called in reference to their masculine nature, were first noticed by Bernard Deschamps more than forty years ago,* but have never been properly studied throughout the butterflies. Deschamps called them plumules, from their feathery tips; but the term is utterly inappropriate to most of them; and their form is so varied that only some word expressing their masculine character should be accepted, since this is their single common peculiarity.

These androconia are very capricious in their occurrence; a number of allied genera may possess them, while a single genus, as closely allied, may be quite destitute. This is true throughout the butterflies, and yet there are large groups in which they are altogether wanting, and others in which their absence is extremely rare. In the highest butterflies, they are long, slender, and invariably feathered at the tip. In one small group (the *Heliconii*), they are toothed as well as feathered. With the exception of the *Heliconii*, they may generally be distinguished from ordinary scales by the absence of any dentation at the tip. In the *Voracia*, they are fringed, and, with a single known exception, their extreme base is expanded into a sort of bulb; elsewhere, even in the other Pierids, they are not fringed, but have a smooth rounded edge. In the *Adolescentes* they assume a battledore or fan shape, with a smooth edge, and are generally beaded, and more heavily striate than the scales. The same is true, but with more variations, in the *Villicantes* and *Ephori*, where they have been considered wanting. In the *Equites*, where also they have been supposed to be wanting, they differ but little from the scales, but are much smaller and more coarsely striate. In the *Urbicolæ*, where no one has hitherto recognized them, they present the greatest variety in the same individ-

* Récherches microscopiques sur l'organisation des ailes des Lépidoptères, Ann. Sc. Nat. [2] III. 111–37 (1835).

ual; in one group (*Hesperides*) there are hair-like androconia, and others which are exceedingly large and spindle-shaped. In the *Astyci*, besides hair-like and gigantic androconia, there are usually some which are spoon-shaped, with long handles.

As a general rule, these androconia are present in the patches to which we have alluded as forming one phase of the antigenic characters of the male; but often, as in the *Adolescentes* and *Voracia*, they are scattered indiscriminately or in rows over the upper surface of the wings; and there are many patches, like those at the base of the hind wings of some *Fugacia*, and next the median vein of the same wing in *Dan. Plexippus*, where androconia are not found. They do, however, sometimes occur in patches on the hind wings, as in the fold next the inner margin of the *Equites;* but, with the exception of the discal spot of the *Ephori*, they seem to be present in all patches found on the front wings; occasionally forming the principal part of such patches, as in the *Callidryades*, and again taking no part in the display. Take, for example, the *Dryades*, where so many small black scales are crowded against certain veins as to give them a thickened appearance; the androconia are also present in great numbers, but entirely concealed; only by removing the scales can even the tassels of their long and slender blades be seen. Perhaps even more curious than this is the arrangement by which all the androconia of the *Equites* and *Hesperides* are tightly enclosed in a fold of the membrane; it is not impossible that this fold can be opened at will by the insect, and it would then become conspicuous, and probably an attraction to the butterfly's mate; but what possible advantage can there be in partially or wholly concealed androconia, scattered separately over the wing? In some *Adolescentes*, they are exceedingly scárce, numbering not more than one to a hundred scales, and the exposed surface of this one not one-tenth that of the scales about it. One might search an hour with a microscope over an unruffled wing and overlook it; indeed, it is as the merest speck of dust in a dust heap. Does the sight of these creatures surpass our power of vision with the microscope? The theory of sexual selection proposed by Darwin appears to fail here, just where it should aid us most.

XIV.

CHARACTERS OF SOME LITTLE-KNOWN OR NEW GENERA OF PLANTS.

By Asa Gray.

Read May 9, 1877.

CANOTIA, Torr., Genus *Rutacearum.*

Flores hermaphroditi. Calyx parvus, quinquelobus, persistens; lobis latis æstivatione imbricatis. Petala 5, hypogyna, oblonga, utrinque obtusissima, basi lata inserta, æstivatione imbricata, intus medio costa prominula instructa, decidua. Stamina 5, hypogyna, calycis lobis opposita: filamenta subulata, petalis parum breviora, persistentia: antheræ oblongo-cordatæ, introrsæ, sinu profundo apici acutissimo filamenti affixæ, mucrone parvo apiculatæ; loculis intus longitudinaliter dehiscentibus. Pollen madidum tricorne. Discus nullus. Ovarium gynobasi crassa eoque multo majore inferne leviter 10-sulcata impositum, 5-loculare, stylo crasso demum elongando superatum: stigma parvum, leviter 5-lobum; loculis ovarii oppositipetalis. Ovula in loculis sæpissime 6, angulo interno biseriatim inserta, subhorizontalia; micropyle infera. Capsula ovato-fusiformis, lignescens, epicarpio tenui subcarnoso induta, 5-locularis, ab apice 10-valvis (primum septicida, mox loculicida), portionibus styli persistens 10-fissilis superatis; columella nulla. Semina in loculis solitaria vel bina loculum implentia, adscendentia, subovata, complanata; testa subcoriacea creberrime papillulosa inferne in alam latam membranaceam nucleo sublongiorem producta. Embryo in strato tenui albuminis carnosi rectus; cotyledonibus ovalibus planis; radicula breviuscula, infera. — Arbuscula 10–20-pedalis, prorsus aphylla, glaberrima; ramis alternis spartioideis viridibus rigidis nunc spinescentibus striatulis cicatricibus parvis remotis brunneis notatis; inflorescentia secus ramulorum racemiformi; pedunculis brevissimis fasciculatim vel cymoso-3–7-floris; pedicellis articulatis; bracteis parvis squamiformibus ovato-subulatis oppositis deciduis; corolla alba; glandulis ordinis evanidis.

CANOTIA HOLACANTHA, Torr. in Pacif. R. Rep. iv. 68; Benth. & Hook. Gen. i. 616 (where the radicle is inadvertently said to be *superior*); Brewer & Watson, Bot. Calif. i. 190. — Arizona, in the arid desert region, especially along mountain water-courses, Emory, Bigelow, and various other collectors, in fruit, first collected in flower by Palmer, and recently by Rothrock in Wheeler's Expedition.

A genus of hitherto undetermined affinity. Dr. Torrey, who knew only the fruit, with calyx and filaments persistent at its base, compared it with *Eucryphia*; upon which Bentham and Hooker appended it, along with that genus and *Euphronia*, to *Rosaceæ*, tribe *Quillajeæ*. Whatever may be said of those genera, this is certainly not Rosaceous. Baillon, the first botanist to publish any thing upon the genus since the flowers were known, and who describes the "discum glandulosum incrassatum" under the ovary (but wrongly describes the calyx as valvate and the ovules as anatropous), refers *Canotia* without question to *Celastraceæ*.* This is better than *Rosaceæ*, and the inferior radicle tells in its favor, as against the view which I take, having now for the first time examined the flowers. But I am confident that the plant belongs to the *Rutaceæ*. The structure of the gynobase, as I should call it, points strongly in this direction. This large and fleshy or, when dry, rather corky body upon which the ovary is mounted is broader than the latter in the blossom, as well as of twice its height; and is so confluent with it that, upon superficial observation, it would be taken for a component part of it. But it is solid within, and has a papillose-glandular surface, unlike that of the ovary it supports, which is smooth. Its likeness to that of Rue is manifest; and in *Thamnosma* the same body becomes stipitiform. I find no trace in *Canotia* of a proper disk around the base of this, which is conspicuous in *Thamnosma*. As the fertilized ovary enlarges, it soon becomes broader than the gynobase as well as longer; in the fruit the latter so inconspicuous that it has been overlooked. The wood and bark are not bitter to the taste, in the manner of most *Simarubaceæ* (which in a comprehensive consideration of relationships must be taken along with *Rutaceæ*), nor is the surface at all pustulate- or tuberculate-glandular as in *Thamnosma*. But in the petals, and especially in the sepals and minute bracts of the inflorescence, I discern evident traces of the Rutaceous oil-glands. Faint and few though they be, they suffice to confirm the affinity.

There are four of these spartioid green-barked and mainly leafless shrubs in the dry Arizonian region. *Thamnosma montanum*, Torr.,

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* Adansonia, x. 18, & Hist. des Plantes, vi. 43, 1875.

which is a genuine *Rutacea; Holacantha Emoryi*, Gray, an undoubted *Simarubacea; Kœberlinia spinosa*, Zucc., which has been referred to the same order, but is more anomalous; and finally *Canotia holacantha*, which, if I mistake not, must take its place among the typical *Rutaceæ*, notwithstanding some anomalies.

The pollen of *Canotia*, as pointed out to me by Prof. Rothrock, who has supplied the best flowering specimens we possess, is exactly represented by Sach's figure of that of *Epilobium*, viz., that in his Lehrbuch, fig. 349.

SYMPETALEIA, Nov. Gen. *Loasacearum*.

Calycis tubus globoso-obconicus; limbus 5-partitus, lobis tubo æquilongis. Corolla (alte gamopetala!) hypocraterimorpha; tubo elongato subclavato intus infra medium piloso-annulato; limbo 5-partito, lobis rotundatis æstivatione imbricatis. Stamina circiter 25, corollæ tubo sub fauce aut inordinate aut 5-seriatim inserta: filamenta brevissima, tenuia: antheræ subreniformes, uniloculares, bivalves. Ovarium uniloculare: stylus filiformis: stigmata 5, brevia, conniventia. Ovula indefinite plurima, placentis 5 parietalibus inserta. Capsula subglobosa, apice tantum dehiscens. Semina perplurima, oblonga; testa tenui conformi oblique striato-costulata. Embryo in albumine parco granuloso axilis, rectus, oblongus; cotyledonibus brevibus.

SYMPETALEIA AUREA. Herba annua, humilis, *Eucnidis* facie, viscoso-hirsutala et setis urentibus lævibus hispida; foliis longe-petiolatis rotundato-cordatis crenatis vel 3–5-lobatis; pedunculis terminalibus et supra-axillaribus, fructiferis elongandis recurvis; corolla aurea semipollicari. — Pulpito Point, Lower California, Dr. Thomas H. Streets, U. S. N. Coll. in February, 1875?

In this we have the anomaly of a Loasaceous plant with a truly gamopetalous corolla! In *Eucnide* of Zuccarini, — a genus which had been merged in *Mentzelia*, but which Mr. Watson, in the Botany of California, has properly reinstated, — the petals are united at the very base into a ring, which bears the stamens. Here they are combined into a long tube, and even to the base of the spreading limb, and the stamens are borne in and below the throat. The imbricated æstivation of the corolla is shared by *Eucnide, Mentzelia*, &c.; but the one-celled anthers, of the Malvaceous pattern, are peculiar. The tube of the calyx is completely adnate to the ovary, which is crowned by a flat disk; and the corolla is epigynous. The habit of the plant is wholly

that of *Eucnide*. The name chosen for the genus expresses its most striking character, viz., the union of the petals.*

LEMMONIA, Nov. Gen. *Hydrophyllacearum.*

Corolla brevi-campanulata, sepala angusto-linearia haud superans, 5-loba, intus nuda. Stamina brevia, tubo corollæ brevissimo æqualiter inserta: filamenta subulata, ad insertionem subito dilatata, quasi appendiculata: antheræ cordato-didymæ. Discus obscurus. Ovarium ovoideum, pilosum, biloculare, stylis 2 brevibus superatum: stigmata capitellata. Ovula in loculis binis, superposita, obovata, anatropa. Capsula ovoidea, retusa, 4-sperma, bivalvis: valvis membranaceis semisepta angusta firmiora ferentibus. Semina ratione capsulæ magna, obovata, grosse rariter ruguloso-impressa; testa tenui cæterum lævi. Embryo cylindricus, rectus, albumine carnoso paullo brevior.

Lemmonia Californica. Herbula annua, depressa, dichotoma, sericeo-canescens: foliis alternis basi apiceque ramorum confertis spathulatis integerrimis; floribus cymoso-congestis et in dichotomis infimis solitariis subsessilibus; sepalis albo-villosis angustissimis apice non latioribus, fructiferis (lineas 2 longis) capsulam superantibus; corolla lineam longa alba seu albida. — San Bernardino Co., California, on Bear Valley Creek, on the head waters of the Mohave River, May, 1876, J. G. Lemmon. This interesting little plant, which was sent to me in a letter by Mr. Lemmon at the time of its discovery, was passed over by me as a *Coldenia* § *Tiquiliopsis*, which it resembles in aspect and especially in mode of growth. But it proves to be the type of a new genus, somewhat related to *Draperia* among the *Phaceliew*, yet belonging properly to the *Nameæ*. It is distinguished from *Nama* by the short campanulate corolla and correspondingly short styles and subulate filaments (the latter dilated and thickened at the very insertion in such manner as to form a sort of annulus to the corolla-tube), and

* In the small but interesting collection of plants of Lower California, made by the discoverer of this genus, occurs a new *Hemizonia*, the characters of which are here appended: —

Hemizonia Streetsii. § *Hartmannia, H. angustifoliæ* et *corymbosæ* sat affinis, humilis, ramosa e radice annua, pubescens, eglandulosa; foliis linearibus nunc integerrimis nunc inciso-4-5-dentatis; capitulis ramos terminantibus brevipedunculatis; ligulis ultra 12 biseriatis elongatis oblongo-spathulatis, tubo brevi glanduloso; paleis receptaculi convexo-conici circa flores disci plurimos steriles basi connatis; pappi paleis fl. disci 8–10 lineari-lanceolatis parum denticulatis corolla paullo brevioribus; acheniis radii lævibus. — San Benito Island, Lower California, Dr. Thomas H. Streets.

by the single pair of ovules to each cell, forming large seeds. The latter are very like those of *Nama demissa* and of *Conanthus*. As to *Phacelia*, which might be thought polymorphous enough to include almost any plant of this sort, even if we disregard the technical character of the distinct styles, yet the geminate ovules and seeds in this plant are characteristic, being superposed, while those of *Phacelia*, when reduced to single pairs, are collateral.

Of late years I have had frequent occasion to associate the name of Mr. J. G. Lemmon with species of his own discovery; and I seize with satisfaction the present opportunity of further commemorating the services of a most ardent and successful explorer of the Sierra Nevada region, by naming in his honor this interesting new genus which he alone has met with. By the specific name, *Californica*, I indicate the principal field of Mr. Lemmon's arduous explorations.

ECHINOSPERMUM, Sect. ECHINOGLOCHIN.

Nuculæ immarginatæ, ovato-trigonæ, dorso (medio carinulato) undique inordinate aculeolatæ, aculeis tota longitudine setulis retrorsis armatis; areola prope basim ovata. Corollæ lobi convoluto-imbricati. Pedicelli fructiferi erecti. Calyx fructifer patens, nec reflexus.

ECHINOSPERMUM GREENEI. *Eritrichio fulvo* sat similis, ultraspithamæum, e radice annua laxe ramosum, pilis albidis striguloso-pubescens; foliis linearibus obtusis; racemis solitariis geminisve laxiusculis hic inde (basi præsertim) folioso-bracteatis; calyce fulvo-sericeo-hirsuto; lobis oblongo-linearibus obtusis corollam albam subæquantibus; nuculis (sesquilineam longis) calyce brevioribus inter aculeas sparsas teretes ($\frac{1}{3}$–$\frac{1}{2}$ lineam longas) tuberculato-scabris intus acute carinatis. — About Yreka, Siskiyou Co., in the northern part of California, 1876, E. L. Greene. An additional and singular link between *Echinospermum* and *Eritrichium*, but technically belonging to the former, if not worthy of generic distinction; remarkable for having the prickles glochidiately barbed not merely at the apex, but for their whole length, and not at all arranged in lateral ranks.

ECHIDIOCARYA, Gray, char. reformatum.

Calyx 5-partitus; segmentis sub fructu parum apertis. Corolla rotato-hypocraterimorpha; tubo calycem subæquante lobis rotundatis breviore, plicis faucialibus pl. m. intrusis. Filamenta brevissima medio tubo inserta: antheræ oblongæ, inclusæ. Stylus brevis: stigma capitatum. Nuculæ ovato-trigonæ, obliquæ, cristulato-rugosæ, dorso ventreque carinatæ, in stipitibus crassis aut discretis aut per paria coalitis

(areolis pl. m. cavis gynobasin late conicam claudentibus) incurvo-adscendentibus. — Herbæ annuæ, diffusæ, *Eritrichii* sect. *Plagiobothridis* facie; foliis omnibus alternis; floribus parvulis albis; pube hirsuta. — Gray in Benth. & Hook. Gen. ii. 854, & Proc. Am. Acad. xi. 89.

Two species are now known, of very similar aspect; and it may now be said of the genus that it should stand between *Eritrichium* and *Antiphytum*.

Echidiocarya Arizonica, Gray, l. c. Corolla fauce plicis minimis fere evanidis parum constricta; nuculis parce cristato-muricatis apice compresso-attenuatis basi productis in stipites crassos iisque æquilongos inferne connatos, areola (paris) excavata maxima cava. — This species was founded on a specimen collected by Dr. Smart, of such peculiar character of fruit that it might have been thought to be abnormal. But it is now confirmed by additional specimens, collected in March of this year, near Tucson, Arizona, by my indefatigable and sharp-sighted correspondent, Rev. E. L. Greene.* It is also confirmed essentially, and the character modified, by the detection of a second species, in which, however, each nutlet has a wholly separate stipe. This species may be named

Echidiocarya Californica. Corolla majore (lobis rotundatis lineas circiter 2 longis) fauce plicis validis puberulis clausa; nuculis minoribus (lineam longis) minus acutatis dorso rugoso-alveolatis (rugis acutis echinulatis), stipitibus brevibus compressis angulo ventrali supra basim ortis discretis, areola carunculiformi parvula concava. — South-eastern California, in San Bernardino Co., 1876, Parry and Lemmon.

LEPTOGLOSSIS, Benth., subgenus Brachyglossis.

Corolla plane hypocraterimorpha; tubo filiformi sub limbo rotato in faucem campanulatam brevem stamina claudentem subito modiceque ampliato. Antheræ fertiles 4, superiores 2–3-plo minores: filamenta quinta ananthera. Ovarium haud stipitatum, disco tenuiter cupulato subtensum. Stylus sub stigmate angustiuscule bilobo bialatus. Semina (*L. Texanæ*) subreniformia, grosse corrugato-rugosa. Embryo in albumine carnoso subincurvus. — Herbæ Texano-Mexicanæ, humiles, e radice perenni diffusæ; floribus majusculis ut videtur albis.

Leptoglossis Texana. Multicaulis e basi firma ut videtur suffrutescente, viscido-pubescens: foliis spathulato-ovalibus vel oblongis

* At the same station Mr. Greene likewise detected the most singular of all our *Borraginaceæ*, viz. *Harpagonella Palmeri*, before known only from Guadalupe Island, Lower California.

acutis plerumque in petiolum brevissimum marginatum attenuatis: calyce infundibuliformi-campanulato pedicello æquilongo vel breviore 5-dentato, dentibus latis acutiusculis; stigmatis lobis spathulatis deorsum in apicem styli alato-decurrentibus. — *Nierembergia* (*Leptoglossis*) *viscosa*, & *Browallia* (*Leptoglossis*) *Texana*, Torr. Bot. Mex. Bound. 155, 156. — Western Texas, Wright, Bigelow. Adjacent Mexico, at San Carlos, Berlandier, no. 3194. The two names above-cited refer to the same plant. It was probably intended that the first should be cancelled.

Leptoglossis Coulteri. Puberula; caulibus debilibus laxis; foliis ovatis oblongisve tenuiter petiolatis; pedicellis longioribus; calycis lobis triangulari-lanceolatis tubo turbinato æquilongis; corollæ fauce subgibbosa: stylo sub stigmatis lobis subito latissime alato. — Mexico, coll. Coulter, no. 1346.

In habit and foliage these two plants are not unlike *Bouchetia*, a genus established by Bentham and Hooker upon one of DeCandolle's two species. The corolla is that of *Nierembergia*, except that the limb is even flatter, or completely rotate, and the stamens are included in a short and abrupt but small faucial enlargement of the very summit of the tube. The five filaments are all short, not far from equal in length; the posterior destitute of anther; the upper anthers small, but polliniferous; the lower pair with far larger fertile anthers. These characters generally accord with *Leptoglossis*, Benth., except in the shortness and comparative smallness of the throat, which in true *Leptoglossis* is tubular-funnelform and continued downward for considerable distance, thus giving the filaments greater length and lowness of insertion. In the style, these plants partake of the peculiar character of the related genus *Reyesia*, Clos (*Pteroglossis*, Miers, which I know only from the two published figures), except that the stigma is manifestly two-lobed. The scarious-membranaceous wing, which is decurrent from these lobes down the apex of the style, was overlooked by Dr. Torrey in our scanty flowers of the Texan species. Its breadth on either side is not quite equal to the length of the thickish stigma lobe. But in the allied Mexican species the whole wing is much broader, and quadrate or slightly cordate, not flabelliform-obcordate as in *Reyesia*. The latter genus, of a single species, seems to be pretty well marked in habit, the complete absence of the fifth stamen, &c. But the two plants here described, notwithstanding their resemblance to *Nierembergia* in general form of the corolla and to *Reyesia* in the winged apex of the style, are probably best disposed of under a subgenus of *Leptoglossis*.

XV.

OBSERVATIONES LICHENOLOGICÆ. No. 4.

OBSERVATIONS ON NORTH AMERICAN AND OTHER LICHENS.

BY EDWARD TUCKERMAN, M.A.

(Continued from Vol. VI. p. 287.)

Read May [illegible], 1877.

PYXINE. The black hypothecium of *Physcia picta* distinguishes it from the rest of the genus and suggests an association with *Pyxine*: to which indeed this *Physcia* is in other respects significantly similar. *Pyxine*, thus enlarged, falls into two sections: —

1. PHYSCIARIA. Apothecia scutelliform. Thallus internally white within. *P. picta* (Sw.). — The species should probably include *Parmelia* [illegible] Fr. united by Nylander with the earlier *P. applanata* Ach.: at least no difference seems to be noted. — *P. picta* occurs now saffron-colored within (*P. erythrocardia* Tuckerm. in Wright *Lich. Cub.* n. 94) like *Pyxine cocoës*; but also probably to be compared in this respect with *Pyxine* [illegible] M. & V. d. B. of the next section.

2. PYXINE PROPR. Apothecia similar at first in a tropical form to those of the first section, but finally blackening all over and lecideine. Thallus soon more or less yellow within. *P. cocoës* (Sw.). — The other supposed species of this section are scarcely well defined. *P. [illegible]* (*P. Meissneri*, of these Obs. 1. in Proc. Acad. Amer. 4. p. 40) might indeed often be taken, and was taken by Meissner, for a *Physcia*; but the margin of the apothecium soon blackens, when the lichen is indistinguishable from the original *Lichen Cocoës* Sw. *Lich. Amer.* [illegible]. — Another of the more tropical exhibitions of *Pyxine* is marked by the [illegible] wrinkling of the upper surface (*P. [illegible]* Nyl. *Lich.* [illegible]), but otherwise is close enough to *P. Cocoës*. — From this may well seem more separable the larger lichen, extending far northward, which furnished Fries the type of the genus (*P. sorediata* Tuckerm. [illegible]), but this differs only in size, and not always in that respect, from forms easily included in *P. Cocoës*.

— The larger form just named is not, however, confined to the north, and exhibits in the tropics a peculiar luxuriance in quadrilocular spores (v. *Eschweileri*, Mihi; given in Wright *Lich. Cub.* n. 94, in part) which renders necessary a modification of the genus-character, though the lichen in question (like *Physcia obscurascens*, Nyl. *Syn.*, as compared with *Physcia obscura*) have little claim to be reckoned a species. And, lastly, it may be said that *Pyxine coccinea*, M. & V. d. B. (*Lich. Jav.* p. 40), which is distinguished, like the last variety, from the var. *sorediata* by rather larger and quadrilocular spores, seems scarcely otherwise to differ from this, but as *P. picta*, v. *erythrocardia*, from the type of that species, or, as *Physcia obscura*, v. *endochrysea*, Hamp. (the oldest name of a repeatedly named anamorphous condition) when the medullary layer has become red from the same when as yet it is only yellow. Systematic Natural History is so much a matter of opinion, that it may sometimes seem difficult, at this day, to fully assert its position in the face of more purely objective science: surely, then, all those who love the study of the system will desire that the term "species" should express something worth knowing; that its value should be enforced and extended rather than diminished and frittered away.

Umbilicaria Caroliniana, sp. nov.: thallo membranaceo lævigato papuloso rotundato-lobato mox polyphyllo complicatoque olivaceo-fusco, subtus lacunoso papillato-granulato atro, fibrillis paucis hinc inde obsito; apotheciis subelevatis mox plicatis deinque papillato-proliferis. Sporæ (2^{nae}?) ellipsoideæ, muriformi-multiloculares, fuscæ, longit. $0{,}030\text{-}40^{mm.}$, crassit. $0{,}020\text{-}23^{mm.}$ — U. *mammulata*, Tuckerm. Syn. N.E. p. 69, *non* Ach. *fide* Nyl. *l. infra cit.* — Rocks, Grandfather Mountain, N. Carolina, *M. A. Curtis*. High mountains of N. Carolina, *S. B. Buckley*. A well-marked *Umbilicaria*, but the material before me for its illustration is small. The plant was pretty confidently referred, at the place cited above, to the North American *Gyrophora mammulata*, Ach. *Syn.*, both from the diagnosis and the name; and this judgment seemed to be confirmed by my notes (made in 1850) on a specimen then preserved in the museum of the Royal Society of Upsal. But Dr. Nylander (*Lich. Scand.* p. 115) says distinctly, that Acharius's lichen is "*spodochroa, apotheciis non rite evolutis*." Dr. T. H. Fries also refers it (*Lich. Scand.* p. 154) to "*spodochroa, rhizinis evolutis vel* (*maximam partem*) *in tubercula nigra mutatis;*" and it is evident that neither of these references is to the North Carolina plant. *U. dictyiza*, Nyl. (*Flora Ratisb.* 1869, p. 388) of the same section of the genus as the lichen above described, is, according to Stizenberger (*Index Lich. Hy-*

perb., p. 22) from Newfoundland; and no description of it is known to me.

STICTA HALLII, sp. nov.: thallo coriaceo reticulato-celluloso subtiliter rimuloso-granulato sparsimque villosiusculo cinereo-glaucescente, laciniis rotundatis subintegris, subtus venoso-costato tomentoso maculis pallidioribus nudis notato; apotheciis sparsis (latit. 2-3 millim.) sessilibus, excipulo villoso integre marginato, disco rufo-fusco. Sporæ naviculares, biloculares, fuscæ, longit. 0,023-36^{mm}., crassit. 0,009-14^{mm}. — Trunks, Oregon, *E. Hall*, 1871. Of the stock of *S. scrobiculata*, and closely approaching this species, from which it yet differs in its more or less villous upper side, its veiny under side, its villous apothecia, and especially in its brown, always bilocular spores, which are not reconcilable with those of the other. Some of the specimens show indications of the peculiar sorediation of *S. scrobiculata*, — a feature characteristical also in *S. anthraspis*, Ach., of the same region. The lichen differs from the older species perhaps less in the thallus, than *S. Oregana* (*Mihi* in Bull. Torr. Bot. Club, April, 1874) from *S. pulmonaria;* but more in the spores. It is dedicated to the discoverer, my friendly correspondent, Elihu Hall.

ERIODERMA VELLIGERUM, sub-sp. nov.: thallo imbricato cinerascente, lobis adscendentibus rotundatis sinuato-incisis margine subcrispis dense hirsutis, subtus sulphureo; apotheciis (2-4 millim. latis) marginalibus extus hirsutis, disco fuscescente. Sporæ octonæ rotundato-ellipsoideæ, simplices, limbatæ, longit. 0,009-16^{mm}., crassit. 0,008-10^{mm}., leviter in thecis infuscatæ dein incolores. — Shores of the Straits of Magellan, *Rev. Dr. Thomas Hill* (Hassler exp. 1872). Not well comparable with such species as *E. polycarpum* and *E. Wrightii*, which exhibit the normal Peltigerine frond, but differing from that exactly as some imbricated and crisped forms of *Peltigera rufescens*. The hirsute upper surface and sulphur-colored under side, as well as the habit of growth, distinguish the lichen from what I have seen of *Erioderma Chilense*, but the last is very near, and said by Montagne to be also imbricate, as it has similar though more rounded spores. I cannot but still consider this little group as belonging to the *Peltigerei*.

PANNARIA SYMPTYCHIA, sp. nov.: thallo foliaceo membranaceo-cartilagineo cæspitoso-polyphyllo livido-fuscescente, lobis sinuato-repandis flexuosis complicatis subtus nudis fuscis; hypothallo obsoleto; apotheciis (latit. c. 1^{mm}.) biatorinis sessilibus, margine tenui integerrimo fusco discum convexum nigrum opacum cingente. Sporæ octonæ, ellipsoideæ, simplices, incolores, longit. 0,009-16^{mm}., crassit. 0,007-10^{mm}., paraphysibus incrassatulis distinctis. — On rocks (apparently) island of Juan Fer-

nandez, *Rev. T. Hill* (Hassler exp. 1872). Thallus with something of the aspect of an *Endocarpon* not remote from *E. miniatum* v. *aquaticum*, Schær., but the internal structure of *Pannaria* § *Coccocarpia*. Collogonidia disposed in short chains. Hymeneal gelatine becoming first blue, and then wine-red with iodine. I cannot compare the species with any other. Spermogones have not occurred.

PANNARIA SONOMENSIS, sp. nov.: thallo parvulo radiante olivaceo, laciniis linearibus ramosis striatis, centralibus teretiusculis dein intricatis, periphericis magis dilatatis flabellatisque dichotomo-multifidis, subtus albis nudis hypothallo obsoleto; apotheciis minutis (0,3-0,4 millim. latis) lecanorinis, margine integro dein excluso, disco e rufo-fusco nigricante. Sporæ fusiformes, curvulæ, simplices, incolores, longit. 0,020-33$^{mm.}$, crassit. 0,002-3$^{mm.}$ Hypothecium pallidum. Paraphyses dein laxæ. — Rocks, Sonoma, and also in the Yosemite Valley, California, *Dr. H. N. Bolander.* Interior of the thallus compact; of elongated cells. Collogonidia solitary or concatenate; reaching 0,018$^{mm.}$ in length by 0,009$^{mm.}$ in width. Spores fusiform in the sense of Koerb. *Syst.* t. 3, f. 5; and they might be called short-acicular. Belongs to the same group with *P. flabellosa* (*Obs. Lich.* l. c. 5, p. 401) and *P. Petersii* (*Gen. Lich.* p. 54). The resemblance of the interior structure of *P. flabellosa* to that of the lichen before us has been well exhibited by Schwendener (*Erört. z. Gonidien-frage, Flora Ratisb.* 1872, p. 227, t. 4) in the infertile Yosemite specimens sent to him as "*Pannariæ affinis.*" It appears quite impossible to remove these plants from *Pannaria;* or to continue to keep *Pterygium*, Nyl. apart from them in genus.

PANNARIA STENOPHYLLA, sp. nov.: thallo orbiculari zonatim centrifugo olivaceo, laciniis tereti-compressiusculis, centro squamuloso-diminutis delabentibus, ambitu radiantibus ramosis, subtus pallidis nudis hypothallo obsoleto; apotheciis lecanorinis perminutis (latit. 0,2-0,3 millim.) disco fusco margine tenui dein disparente. Sporæ ex ellipsoideo oblongæ, sæpe curvulæ, biloculares, longit. 0,012-20$^{mm.}$, crassit 0,003-5$^{mm.}$ — Lime rocks, Moulton, Alabama, *Hon. T. M. Peters*, 1874. Thallus from a quarter to little more than half an inch in diameter. Structure of the interior of the thallus as in the last species; collogonidia in chains; at length 0,012-20$^{mm.}$ long, and 0,010-12 $^{mm.}$ thick. The lichen grows with and often commingled with *P. Petersii*, from which it is readily distinguishable by its smaller size, lighter color both of thallus and fruit and terete lobes. *P. Sonomensis* is nearer, but exhibits a different habit of growth, and the spores are quite irreconcilable with those of the Alabama lichen.

SYNALISSA MELAMBOLA, sp. nov.: thallo effuso rimoso-areolato nigro, areolis planiusculis (latit. dein plusquam 1 millim.) stipitato-elevatis polycarpis; apotheciis (0,1-0,3 millim. latis) innatis lecanorinis disco subpapillato concolore marginem tenuem persistentem demum superante. Sporæ octonæ, ellipsoideæ, simplices, incolores, longit. 0,010-12$^{mm.}$, crassit. 0,005-8$^{mm.}$; paraphysibus omnino conglutinatis. — Lime rocks, Alabama, *Hon. T. M. Peters*. Thallus cellulose; the collogonidia solitary. The reaction of the hymeneal gelatine with iodine is blue. Plant noticeable for its large, flattish, black areoles, which the lens shows to contain from two to six or more very minute but quite regular apothecia.

SYNALISSA VIRIDI-RUFA, sp. nov.: thallo effuso granuloso mox rimuloso-diffracto fusco-viridi; apotheciis (latit. 0,2-0,4 millim., visis) lecanorinis adnatis subplanis, disco rufo, margine subpersistente. Sporæ octonæ, ellipsoideæ, limbatæ, incolores, longit. 0,016-18$^{mm.}$, crassit. 0,008-10$^{mm.}$; paraphyses conglutinatæ. — Lime rocks, Texas, *C. Wright*. Structure not very different from that of the last; rounded, green cellules, with mostly solitary collogonidia, which reach a diameter of 12-15 mic. The reaction with iodine also as in the last. The lichen is marked among our species of this group by its rather brighter colors.

OMPHALARIA KANSANA, sp. nov.: thallo pulvinato coriaceo-cartilagineo atro e lobulis stipitatis erectis clavatis vel sublobatis vel fructu dilatato pileatis; apotheciis (0,5-0,8 millim. latis) terminalibus concoloribus mox convexis margine disparente. Sporæ — 12-^{nae} in thecis ventricosis, ex ellipsoideo dein ovoideo-oblongæ, medioque constrictæ, simplices (tenuiter demum uniseptatæ?) incolores, longit. 0,005-8$^{mm.}$, crassit. 0,003-4$^{mm.}$, paraphysibus bene distinctis. — On lime rocks, Chase County, Kansas, *E. Hall*, 1871. Reaction with iodine, blue. Collogonidia mostly collected into small clusters of 3-5, amidst anastomosing filaments, which alone occupy the centre of the thallus: the structure of *O. corallodes* (Mass.) Nyl., with which the Kansas lichen appears best to agree generally. The two species differ from OMPHALARIA PROPER, as here understood (*Gen. Lich.* p. 81) with umbilicate thallus, in forming cushions of stalked lobes, which become more or less lobulate above. However ill exhibited this lobate or foliaceous character, it seems enough to give these plants a higher place in the system than that of *Synalissa symphorea*. The Kansas lichen is, so far as seen, a smaller species than the European with which it is above compared, and less evidently foliaceous. It is characterized at sight by its elevated convex apothecia, looking like nail-heads.

LEPTOGIUM RIVALE, sp. nov.: thallo membranaceo microphyllino

plumbeo, lobis imbricatis linearibus planis repandis; apotheciis (ostiolis indicatis) immersis. Sporæ octonæ, e fusiformi ovoideæ, biloculares, incolores, longit. 0,016-23$^{mm.}$, crassit. 0,005-8$^{mm.}$. Paraphyses parcæ. — "On small pebbles in the bottom of a clear brook around the Big Trees, Mariposa," California (growing with and on *Hydrothyria*, Russ.) *Dr. Bolander*. Lobes scarcely exceeding 0,5 millim. in width. Texture of the thallus parenchymatous throughout; an outer row of polygonous cells, distinguishable from the rounder and looser cells of the interior, indicating the *cortex* of the present genus. Collogonidia solitary, or in very short chains. There is little in the lichen to remind one of the equivocal *Collema rivulare*, Ach., of Sweden, which yet agrees with the other in the very interesting points of an entirely cellulose texture and an aquatic habitat. The Californian plant was supposed to be infertile; but my friend Dr. Schwendener met accidentally with an immersed apothecium in a section of the thallus which he was examining, and I have since found such fruits to be indicated externally by a distinct ostiolar margin. Whether there is ever any further development or emergence of this apothecium is unknown. The small material before me gave no indication of lichenine with iodine.

PLACODIUM GALACTOPHYLLUM, sp. nov.: thallo crustaceo-adnato areolato-squamuloso ambitu lobato, farinoso lacteo, detrito fulvo; apotheciis (latit. 0,5-0,9 millim.) zeorinis sessilibus planis disco aurantiaco tenuiter marginato. Sporæ octonæ, polari-biloculares, incolores, longit. 0,008-14$^{mm.}$, crassit. 0,004-6$^{mm.}$. Tuckerm. *Gen. Lich.* p. 108. — On lime rocks, Chase Co., Kansas, *E. Hall*, 1871. A distinctly lobed lichen with the habit of *Lecanora muralis* v. *albo-pulverulenta*, Schær. (*Lich. Helv.* n. 334) and differing in this respect from even the best condition of the European *P. erythrocarpium*; the spores of which are also larger, and not rarely measure, in my specimens $\frac{16-23}{8-10}$ mic. Apothecium of our lichen distinctly lecanorine, with marginate disk.

PLACODIUM FERRUGINOSUM, sp. nov.: thallo crustaceo rimoso-areolato aurantiaco, areolis subinde lobulatis, hypothallo nigro; apotheciis (latit. 0,6-0,9 millim.) biatorinis sessilibus ferrugineis (nigricantibusque) margine demum flexuoso. Sporæ octonæ, polari-biloculares, incolores, longit. 0,016-21$^{mm.}$, crassit. 0,006-9$^{mm.}$. — Volcanic rocks, Island of Chiloe, Chili, *Dr. T. Hill* (Hassler exp. 1872). Almost *P. cinnabarinum*, as respects the thallus, but with the apothecia almost of *P. ferrugineum*.

PLACODIUM FERRUGINEUM (Huds.) Hepp, * MINIACEUM; apotheciis miniatis. — On bushes, Cape of Good Hope, *C. Wright*. The appressed apothecia differing only, but remarkably, in color, from Cape specimens of *P. ferrugineum* (*Drege* in herb. Sonder; *Wright*), which are undistinguishable from the northern lichen.

PLACODIUM ATROALBUM; thallo tenui granuloso dein et rimoso-areolato luteolo-fuscescente; apotheciis (latit. c. 0,3-0,5 mm.) adnatis zeorinis, margine thallino tenui demisso integro albo discum marginatum nigrum nudum cingente, intus incoloribus. Sporæ octonæ, ellipsoideæ, polari-biloculares sporobl. approximatis, longit. 0,014-23$^{mm.}$, crassit. 0,005-9$^{mm.}$, paraphysibus filiformibus fusco-capitulatis demum distinctis articulatisque. — On cretaceous sandstone and chalcedony, North Platte, Rocky Mountains, *Dr. Hayden*. Lime rocks, Utah, *Mr. Lapham*. Of the stock of *P. variabile* (Pers.) Nyl., which occurs with well-marked distinctness from this in the same region; and closely associable with the *P. Agardhianum* of Anz. *Lich. Langob.* n. 37. But our lichen is scarcely as well comparable with the *P. Agardhianum* of Hepp (*Lich. exs.* n. 407), and differs still more from the specimen before me of *Pyrenodesmia Agardhiana*, Mass. (Arn. *in herb.* Koerb.), which is wholly lecideoid. This last is represented here by a lichen of the Alabama lime rocks (*Judge Peters*). If all these be to be taken for states of the same *variable* species, our Rocky Mountain lichen above described is, with little doubt, another. The polar type is not easily made out in the spores of the latter; which, but for the other structure of the hymenium, might be supposed rather a *Lecanora* akin to *L. erysibe* (Ach.), Nyl. There are no reactions of the thallus with potash or chloride of lime.

LECANORA SEMITENSIS, sub-sp. nov.: thallo e squamulis glebosis stramineis mox crenato-lobatis subinde hypothallo nigro marginatis; apotheciis (0$^{mm.}$, 7-1$^{mm.}$ latis) appressis plano-convexis tumentibusque congestis, disco livido-fuscescente albido-pruinoso, margine demum subgranulato vel excluso. Hypothecium incolor. Sporæ octonæ ellipsoideæ simplices incolores, longit. 0,011-16$^{mm.}$, crassit. 0,005-6$^{mm.}$. — Granitic rocks, Yosemite Valley, California, *Dr. Bolander*. Clearly a member of the *Saxicola* group, and very close to *L. saxicola v. diffracta*, from which (largely exhibited on the Californian rocks) the present differs in its scaly thallus, which is not radiant, and the ultimate development of its fruit.

LECANORA GLAUCOVIRENS, sp. nov.: thallo crustaceo orbiculari verruculoso-granulato viridi-glaucescente versus ambitum albido, hypothallo incolore; apotheciis (latit. 0$^{mm.}$, 7-1$^{mm.}$) appressis, disco mox convexo e livido-fusco nigrescente, margine integerrimo. Hypothecium pallidum. Sporæ octonæ, ellipsoideæ, simplices, incolores, longit. 0,014-17$^{mm.}$, crassit. 0,006-9, paraphysibus conglutinatis. Spermatia acicularia arcuata.

On bark, Galapagos Islands, South America, *Rev. T. Hill* (Hassler

Exp.). Of the stock of *L. subfusca*, but with rather the habit of conditions of *Rinodina sophodes*. Patches about an inch in diameter.

LECANORA DENTILABRA, sp. nov.: thallo crustaceo tenui areolato-verrucoso glaucescente; apotheciis (latit. $0^{mm.}$, 5-$0^{mm.}$, 9) adnatis, margine tumidulo mox fisso-subcrenato, disco fusco opaco plano vel demum tumente marginemque excludente. Hypothecium incolor. Sporæ octonæ, ellipsoideæ, simplices, incolores, longit. 0,012-$25^{mm.}$, crassit. 0,010-$16^{mm.}$, paraphysibus conglutinatis.

On bark, Island of Chiloe, Chili, and at Sandy Point, Straits of Magellan, *Rev. T. Hill* (Hassler exp.). Without doubt also of the *subfusca* stock, the apothecia being characterized much as those of the rupicoline *L. cæsio-alba*, Koerb., of Europe.

LECANORA OROSTHEA (Sm. *L. expallens*, Ach.) var. JAPONICA; apotheciis (latit. 2-3 millim.) elevato-sessilibus flexuoso-lobatis; sporis longit. 0,020-$23^{mm.}$, crassit. 0,008-$14^{mm.}$. — On beech-trunks in the mountains near Hakodadi, Japan, *C. Wright* (U. S. N. Pac. Exp.). Closely associable with our luxuriant North American condition of *L. orosthea*, but differs in the development of the apothecia and the larger spores, which I have only seen in $4^{s.}$ and $6^{s.}$, in the thekes. *L. orosthea* perhaps deserves the rank of a sub-species under *L. varia*.

LECANORA FRANCISCANA; thallo verruculoso-granuloso albo-cinerascente; apotheciis (latit. 0,7-1,5 mm.) pseudo-biatorinis liberis e fusco-rufo nigris mox convexis turgidisque marginem concolorem excludentibus. Hypothecium subduplex, superius incolor, inferius crassiusque fuscescens; strato gonimo impositum. Sporæ octonæ, ex ellipsoideo mox oblongæ, biloculares, incolores, longit. 0,013-$23^{mm.}$, crassit. 0,003-$5^{mm.}$, paraphysibus coalitis. — On sandstone, San Francisco, Cal., *Dr. Bolander*. A sub-species probably of *L. erysibe* (Ach.) Nyl. Apothecia with the aspect of a *Lecidea* not very unlike a condition of *L. enteroleuca*, Ach., of the same rocks, but really biatorine, except that the hypothecium rests on the gonimous layer. The reaction of the hymeneal gelatine with iodine is blue.

RINODINA RADIATA: thallo crustaceo rimoso-areolato ambitu radioso-lobato glaucescente, hypothallo nigro; apotheciis (latit. 0,3-0,7 mm.) innatis dein emergentibus, disco plano-convexo tumidovo nigro albo-pruinoso, margine thallino integro demum disparente. Hypothecium fusco-nigrum. Sporæ octonæ, brevi-ellipsoideæ obtusæ, biloculares, fuscæ, longit. 0,007-$12^{mm.}$, crassit. 0,005-$7^{mm.}$, paraphysibus conglutinatis. — *Buellia radiata*, Mihi in Lich. Calif. p. 25.

b, thallo depauperato hypothallo radiante subfimbriato. Rocks on the coast of California, *Bolander*. Referred to *Buellia* at the place

cited, notwithstanding the now clear thalline border, on account of the black hypothecium, and the evident resemblance to *B. albo-atra*. But *Rinodina* makes many approaches to *Buellia*, and the color of the hypothecium proves to be an insufficient criterion. Nylander, indeed (*Obs. Pyren.* p. 52) has referred *Buellia albo-atra* to the group now before us; the reference being, however, determined by the presence of truly jointed sterigmas. I have been unable myself as yet to find multi-articulate sterigmas in the specimens examined of this species, or of that described above, but what might rather be taken for sub-simple forms of the organ in question occur sometimes with a few swollen joints. As originally observed, this lichen appeared comparable rather, as respects thallus, with such effigurate ones as *Lecanora circinata;* but the best developed plant (San Diego, *Herb Willey*) has a laciniate circumference like that of *Placodium candicans;* while on the other hand depauperate conditions occur with no trace of a lobulate margin.

Rinodina thysanota, sp. nov.: thallo crustaceo verrucoso ambitu radioso-lobato fusco-olivaceo; apotheciis (qu. visis 0,5-0,7 mm. latis) lecanorinis sessilibus, margine tumidulo integro discum nigro-fuscum cingente. Hypothecium pallidum. Sporæ octonæ, brevi-ellipsoideæ, biloculares, fuscæ, longit. 0,010-14$^{\text{mm.}}$, crassit. 0,005-6$^{\text{mm.}}$.

Rocks, alt. 7,000 feet, in Alpine County, California, *J. A. Lapham.* Thallus, in the single specimen, differenced much as in *R. oreina.* Reaction of the hymeneal gelatine with iodine, blue.

Rinodina mamillana, Tuckerm. Lich. Hawai. in Proceed. Amer. Acad., 7, p. 226, has been collected more recently in the Galapagos Islands, *Rev. T. Hill* (Hassler exp.). Apothecia of both lichens similar in size (0,3-0,8$^{\text{mm.}}$ wide), but the specimens of that from the Galapagos not exhibiting the peculiar protuberance and plaiting of the disk which suggested the specific name, and their thalline margin at length blackening. Hypothecium in both blackish-brown. Spores, 0,012-20$^{\text{mm.}}$ long and 0,005-10$^{\text{mm.}}$ thick; the paraphyses at length distinct. Thallus higher-or sulphur- colored in the South American plant.

Rinodina ochrotis: thallo crustaceo granuloso mox fatiscente furfuraceo albido; apotheciis (qu. visis circ. 0,5 mm. latis) lecanorinis sessilibus, disco e livido-carneo fuscescente, margine obtuso integro. Hypothecium pallidum. Sporæ parvæ, obtuse ellipsoideæ, biloculares, fuscæ, diam. 2-3° longiores. — *Lecanora, Mihi* in Wright *Lich. Cub.* n. 115.

On charred surfaces of logs, Monte Verde, Island of Cuba, *C. Wright.* The description was reserved in hope of other specimens being sent. In the absence of such, I can now add nothing to the above.

Rinodina milliaria, sp. nov.: thallo crustaceo tenui verruculoso viridi-fuscescente; apotheciis perminutis (latit. circa 0,2-0,4 mm.) adnatis lecanorinis, disco fusco-nigro opaco plano-convexo, margine tenui integro dein nigricante vel excluso. Hypothecium fusco-nigrum. Sporæ octonæ, obtuse ellipsoideæ, biloculares, fuscæ, longit. 0,009-15$^{mm.}$, crassit. 0,005-8$^{mm.}$, paraphysibus demum distinctis, fusco-capitulatis.

A common bark-lichen about Boston, and found also at New Bedford, *H. Willey;* and in Western New York, *Miss Wilson.* It is differenced from ordinary *R. sophodes v. exigua* by its blackened hypothecium, — a character, in this place, of some interest. The spores occur now in twelves according to Mr. Willey, a variation like the well-known one in the v. *exigua* (constituting *R. polyspora*, Th. Fr.). But our lichen is also curious as seeming to exhibit filiform, bowed spermatia (0,012-20$^{mm.}$ long) on simple sterigmas. This observation has been made repeatedly both by Mr. Willey and myself, and we are unable to refer the black, papillæform spermogones and contents in question to any other lichen than the one upon whose thallus they occur, though it appears quite inadmissible, in present knowledge, that they can belong to it.

Pertusaria thamnoplaca, sp. nov.: thallo fruticuloso cartilagineo appresso dichotomo-ramoso albido-fuscescente, ramis subteretibus papillato-verrucosis subtus albis fibrillis sparsis concoloribus; apotheciis depresso-globosis monothalamis mox papillato-coronatis (latit. dein 1 mm.) ostiolo punctiformi nigro. Sporæ octonæ, ellipsoideæ, simplices, incolores, longit. 0,050-72$^{mm.}$, crassit. 0,023-38$^{mm.}$.

Trunks, Sholl Bay, near the western entrance of the Straits of Magellan, growing with and often on the next, *Rev. T. Hill* (Hassler exp. 1872). Another illustration of the fruticulose thallus in a properly crustaceous group; and more remarkable than either of those described from our own Pacific coast (Lich. Calif. *in loc.*). Thallus (reaching a diameter of more than two inches) closely appressed and affixed by its fibrils to the matrix, dichotomously much branched, either terete or now a little compressed, and in the larger parts almost attaining a thickness of one millimetre. The whole is besprinkled, at length densely, with crowded papillæ, which surround the apothecia with one or more coronals, and hide often, to a considerable degree, the branches. Under the microscope, the direction of the very minute and confused network of filaments which makes up the interior of the thallus is seen to be on the whole longitudinal.

Pertusaria colobina: thallo crustaceo uniformi papillifero, papillis dein confertis, centralibusque subelevatis; apotheciis ab iis *P. tham-*

noplacæ vix distinguendis nisi sporis minoribus longit. circ. 0,046-56$^{mm.}$, crassit. 0,023-26$^{mm.}$.

With the last, at Sholl Bay, and also, on bark, in the Galapagos Islands, *Rev. T. Hill* (Hassler exp. 1872). The material does not enable me to explain the true relation of this lichen to that immediately preceding. With so much agreement in the fruit, the differences in the thallus are startling; while yet specimens of each, well covered with papillæ, may be supposed at sight the same.

PERTUSARIA AMBIGENS: thallo cartilagineo lævigato subinde rugoso-verrucoso glaucescente; apotheciis lecanorinis (latit. 0,6-1,8$^{mm.}$) sessilibus vel subelevatis 1-2-thalamis, margine thallino lacero-subcrenato demum repetito-duplicato discum planum viridi-cæsium cingente. Sporæ octonæ, ellipsoideæ, simplices, incolores, 0,017-23$^{mm.}$, longæ, 0,008-12$^{mm.}$ crassæ; paraphysibus capillaribus. *Lecanora ambigens*, Nyl. *Enum. Gén. Lich.* p. 113, and *Prodr. Fl. Nov. Granat.* p. 40, not.

On trunks, Oregon, at 49° N. lat., *Dr. Lyall;* and elsewhere in the same country, *E. Hall.* The lichen does not differ from a Cape of Good Hope plant (*Zeyher in herb. Sonder*), also on bark, which is, without doubt, what Nylander has described (*Prodr. N. Granat.*) from the same herbarium. And, so far as appears, it fully agrees also with a rock lichen collected by Mr. Wright at the Cape, and long since determined by Nylander as his *Lecanora ambigens*. The spore-features vary somewhat from the *Pertusaria* type, and appear to have influenced the first describer in excluding the lichen from the genus to which, however, he admits that it perhaps rather belongs. I can entertain no doubt of this. Nothing illustrates so well the very peculiar differentiation of the apothecia as forms associable more or less closely with *Pertusaria velata;* and specimens of *P. velata * multipuncta* are before me which are hardly, at first sight, distinguishable but by the spores. These apothecia (in the Oregon plant) present at length much the appearance in small of a pile of plates; the margin of the elevated apothecium gaping horizontally into two, three, or more margins. Spores enveloped in a halo in both the American and African lichens. The spores of ours agree very well in size with my measurements of the African (*herb. Sonder*), but Nylander (l. c.) gives rather larger figures, or 0,023-30$^{mm.}$ longit. and 0,010-11$^{mm.}$ crassit.

PERTUSARIA FLAVICUNDA, sp. nov.: thallo cartilagineo lævigato verrucoso-areolato pallide sulphureo, areolis ambitus radiose subconcrescentibus; apotheciis depresso-globosis (latit. 1-1,5 mm.) monothalamis, ostiolo mox dilatato hymenium nigricantem pulvere lutulento adspersum

exhibente. Sporæ 2-3^{nae} in thecis, ellipsoideæ, simplices, incolores, 0,060-80$^{mm.}$ longis, 0,040-50$^{mm.}$ crassis.

Rocks, San Diego, California, *Dr. J. G. Cooper;* and received, also, in excellent condition from other collectors (*Herb. Willey*).

PERTUSARIA EUGLYPTA, sp. nov.: thallo cartilagineo insculpto-rimoso glauco-cinerascente; apotheciis sub-globosis (latit. 1-1,8 mm.) pleiothalamis, circum ostiola punctiformia nigra depressis. Sporæ 3-6^{nae}, ellipsoideæ, simplices, incolores, longit. 0,092-138$^{mm.}$, crassit. 0,040-60$^{mm.}$.

Granitic rocks, Cape of Good Hope, *C. Wright.* Comparable with states of *P. communis*, Auct. (*pertusa* (L.) Ach.), but differing in the spores, and in its elegantly sculptured crust, which reminds one of a cuneiform inscription.

PERTUSARIA ALBINEA, sp. nov.: thallo tenui rimuloso-areolato lacteo lineis nigris decussato; apotheciis depresso-hemisphæricis deplanatisque pleiothalamis (latit. 0,5-0,8 mm.) ostiolis minimis punctiformibus nigris. Sporæ octonæ, ellipsoideæ, simplices, incolores, longit. 0,043-58$^{mm.}$, crassit. 0,023-40$^{mm.}$.

On bark, Galapagos Islands, *Rev. T. Hill* (Hassler exp. 1872). Distinguishable from *P. leioplaca* by habit, and the smallness of its parts.

THELOTREMA CALIFORNICUM, sp. nov.: thallo subtartareo verruculoso pallide ochroleüco; apotheciis lecanoroideis (longit. 0,3-0,7 mm.) adnatis sub-planis, excipulo exteriori margine obtuso integerrimo thallino discum nigrum velo margine concolore perforato subvestitum includente, demum flexuoso-irregularibus stellatis lirellatisque. Sporæ octonæ, ex ellipsoideo dactyloideæ, 4-8-loculares, loculis integris, fuscæ, longit. 0,020-30$^{mm.}$, crassit. 0,005-8$^{mm.}$.

On bark, San Diego, California, *Dr. E. Palmer* (Herb. Willey). The whole of the interior of the disk is black, without distinguishable proper margin, and the general aspect is that of *Lecanora;* but the spores, and the crustaceous veil, which is more or less exhibited, appear to associate the lichen with *Thelotrema*, though I know of no species to compare it with. Apothecia now suggesting those of *Chiodecton sphærale.* There is no reaction of the hymeneal gelatine with iodine; nor of the thalline tissues with liquor potassæ or hypochlorite of lime.

PILOPHORUS ACICULARIS (Ach.) Tuckerm. *Gen.* p. 146, f. HALLII; apotheciis elongatis (longit. 2-4 mm., crassit. 0,5 mm. — 1 mm.) pistilliformibus. — On rocks, Cascade Mountains, Oregon, *E. Hall.* The apothecia of *Pilophorus* pass from a globular, often depressed figure, as in f. *Fibula*, into a slightly conical one, like an elevated skull-cap (πῖλος), as in the original f. *acicularis.* And the last is lengthened in the present so as to resemble a pestle. As compared with the other

forms, the podetia of this are short and stout, the whole length scarcely exceeding, in the specimens, thrice that of the longest apothecia. Spores of the species, 0,016-23$^{mm.}$ long and 0,007-8$^{mm.}$ thick. — All the known forms of *Pilophorus* fall readily under one species; there are no satisfactory characters to distinguish them. But it is more difficult to follow Dr. Th. Fries in his recent reference hither (*Lich. Scand.* p. 55) of one of the two states of his *Stereocaulon cereolinum*, *Monog. Stereoc.* p. 40, which is otherwise universally recognized as a *Stereocaulon*; and, as he says, is only with extreme difficulty ("*ægerrime*," *Lich. Scand.* l. c.) distinguishable from the other form. The "good" figure of Ach. *Meth.*, of the fertile condition of *S. cereolus*, is not cited in this reference of the plant to *Pilophorus*. It is surprising, if Acharius really had *Pilophorus fibula* in fruit, before him, when he described his *Stereoc. cereolus*, that he should not at once have recognized the resemblance of the former to his *Cladonia acicularis*. Such mistake could hardly occur here, where the *Pilophorus* is scarcely known but as fertile, and the somewhat similar, commonly sterile, often subsimple lichen, with powdery heads, is most readily and often certainly referable to the *Stereocaulon*.*

BIATORA CAULOPHYLLA, sp. nov.: thallo e lobulis stipitiformi-erectis compressis sursum dilatatis lobatisque griseo-virescentibus in crustam plicatam subinde albo-farinosam stipatis; apotheciis mediocribus (dein et 2 mm. latis) margine obtuso mox livescenti-nigro discum planum rufo-fuscum nigrumque cingente. Sporæ octonæ, ovoideo-ellipsoideæ, simplices, incolores, longit. 0,007-13$^{mm.}$, crassit. 0,004-6$^{mm.}$, paraphysibus conglutinatis. — On rocks, mountains of California, *Dr. Bolander*. The erect lobes are at length 5-7 mm. long, and, in their widest portions, 2-3 mm. wide. This is a pronounced exhibition in the squamulose *Biatoræ* of the extraordinary modification of thallus in *Lecidea vesicularis* (Hoffm.), Ach., and *L. conglomerata*, Ach. As in *Lecanora thamnoplaca*, Tuckerm. (*Gen. Lich.* p. 113) the stipitate lobes of the lichen before us are comparable, in fact, with those of *L. rubina*, v. *complicata* (Anz. *Lich. Ital.* p. 158), the type of which is an almost foliaceous, and in every way distinguished representative of the crustaceous thallus. And, as with the *Lecideæ* just named, there is no species to which our *Biatora* should be referable as a sub-caulescent overgrowth. But this is scarcely as clear in the case of some other stipitate-lobate lichens: *L. thamnina*, noticed in *Gen. Lich.* p. 120, being probably inseparable from luxuriant Californian conditions of *L. cervina* b. *squa-*

* In the above cited *Gen. Lich.* p. 146, note, the spores of the f. *robustus* should be said to be 0,016-23$^{mm.}$ long.

mulosa, Fr., and *Lecidea caulescens*, Anz. (*Lich. Langob.* n. 139) as close, in all respects, to *L. squalida* (Schleich.) Ach. Curious as it is then, too much stress should perhaps not be laid on the systematic value of the thallus we have been considering.

BIATORA PETRI, sp. nov.: thallo e squamis membranaceo-cartilagineis ex orbiculato- oblongo-difformibus undulato-lobatis subimbricatis glauco-cinerascentibus (fuscescentibus) subtus ambituque ascendente mox fuscis; apotheciis marginalibus sessilibus nitidis (latit. 1-2 mm.) disco subplano rufo (nigro) margine flexuoso nigro demum excluso. Sporæ octonæ, ovoideo-ellipsoideæ, simplices, incolores, longit. 0,009-11$^{mm.}$, crassit. 0,004-5$^{mm.}$, paraphysibus coalitis.

On lime and other rocks, growing over mosses, Moulton, Alabama; *Hon. T. M. Peters*. The smooth scales at length reticulately rimulose, as common especially in *B. globifera* (Ach.), Fr.; but the lichen is readily distinguished from the species named, as from *B. Russellii* and *B. luridella* of these papers, by the colors, and the thinness of the loosely aggregated thallus.

BIATORA CARNULENTA, sp. nov.: thallo obsoleto; apotheciis parvis (latit. 0,3-0,6 mm.) adnatis convexis ex albido livescenti-carneolis, margine perquam tenui demisso obscurato vel sæpius evanido. Hypothecium incolor. Sporæ octonæ, ovoideo-ellipsoideæ, simplices, incolores, longit. 0,007-12$^{mm.}$, crassit. 0,003-5$^{mm.}$, paraphysibus conglutinatis. — Dead, soft wood in the White Mountains. Found also on the same substrate at Geneseo, N. Y., *H. Willey*. Reaction of the hymeneal gelatine with iodine, blue.

BIATORA PELIASPIS, sp. nov.: thallo tenuissimo albido vel obsoleto; apotheciis parvis (latit. 0,3-0,6 mm.) sessilibus subplanis, disco livido-fuscescente pruinato, margine tenui nigro disparente. Hypothecium fusco-nigrum. Sporæ ellipsoideæ, simplices, incolores, longit. 0,005-11 mm., crassit. 0,003-5 mm., paraphysibus conglutinatis. — On dead, soft wood, South Carolina, *H. W. Ravenel*, &c.; Massachusetts, *H. Willey*. Very close to this is a minute lichen (*B. peliaspistes, Mihi herb.*) found by me on living hemlock trunks, with leprous-granulose, white thallus; and on dead, soft wood, without thallus, in the White Mountains, in which the apothecia are always naked, and the spores rather smaller (0,005-11 mm. long, and 0,0025-35 mm. thick) and oblong. Both lichens long represented with me the old "*Biatora anomala*" of authors. Both exhibit with iodine the same blue reaction.

BIATORA GLAUCONIGRANS, sp. nov.: thallo granuloso glaucescente; apotheciis (latit. 0,2-0,5 mm.) sessilibus mox convexis e livido-fusco

nigris, margine tenuissimo demisso mox nigricante vel evanido. Hypothecium nigrum. Sporæ octonæ, ex ellipsoideo oblongæ, biloculares, incolores, longit. 0,009-15$^{mm.}$, crassit. 0,003-4$^{mm.}$, paraphysibus coalitis. — On the bark of white pine, New Bedford, Mass., *Mr. Willey.* The well-developed crust, the hypothecium, and the paraphyses distinguish this from *B. lenticularis* (Ach.), &c.

Biatora livido-nigricans, sp. nov.: thallo e granulis cartilagineis discretis livido-glaucescentibus; apotheciis minutis (latit. 0,2-0,4 mm.) sessilibus planis tenuiter marginatis fusco-nigris. Hypothecium pallidum. Sporæ octonæ, dactyloideæ et oblongæ, 4-5-loculares, incolores, longit. 0,015-23$^{mm.}$, crassit. 0,003-6$^{mm.}$, paraphysibus distinctis, capitulatis. — On bark, Sandy Point, Straits of Magellan, *Rev. T. Hill* (Hassler exp. 1872). Specimen a very small one, but the characters sufficient to distinguish the lichen from *Lecidea sororiella*, Nyl., of New Grenada (Lindig *exs.* n. 2838) as from the Australian *L. livido-fusca*, Nyl. (*Syn. N. Caled.* p. 42, not.) and *L. livido-fuscescens*, Nyl., of Brazil (*Flora*, 1869, p. 122), all of which are taken by their author to relate nearly to *Biatora trachona*, Flot. With iodine a vinous tint is exhibited by the hymeneal gelatine of the antarctic lichen, following a bluish.

Lecidea mamillana, sp. nov.: thallo squamaceo-areolato viridi-glaucescente (cinerascente aut dealbato) areolis mox turgescentibus radiatimque striatulis ambitu sublobatis, discretis vel dein aggregatis; apotheciis in areolis innatis centralibus minutis (latit. 0,3-0,7 mm.) plano-convexis nudis margine tenui evanido. Hypothecium fuscum. Sporæ octonæ, ellipsoideæ, simplices, incolores, longit. 0,009-18$^{mm.}$, crassit. 0,005-9$^{mm.}$, paraphysibus conglutinatis. Spermatia minuta, recta, in sterigmatibus simpliciusculis. — On lime rocks, Alabama, *Judge Peters.* Suggests *L. mammillaris* (Gouan) Duf., of the south of Europe; but the areoles, for the most part, are little more than a quarter of the size of those of the European lichen. They occur now in a reduced, glebous state, which is quite smooth, glaucescent, and finally crowded into a close crust; but are more commonly discrete, when the effigurate margin is manifest, the color often darkens, and the surface is at length prettily marked with striæ radiating from the apothecium, instead of becoming cancellated, as in the foreign plant. As seen in section, no important differences are observed in the internal structure of the apothecium of our lichen from that of *L. mammillaris*, though the thinner hypothecium of ours is possibly also paler. I cannot recognize in either the distinctly twofold hypothecium sometimes attributed to this group of *Lecideæ*.

Lecidea psephota, sp. nov.: thallo areolato albo, areolis minutis tumidulis discretis, hypothallo nigro; apotheciis perminutis (latit. 0,2-0,4 mm.) areolis plerumque immixtis e concavo planis margine tenui incurvo persistente, sæpe anguloso-difformibus. Hypothecium nigrum. Sporæ in thecis ventricosis octonæ, ellipsoideæ, simplices, incolores, longit. 0,012-20$^{mm.}$, crassit. 0,007-10$^{mm.}$, paraphysibus concretis. — On granite rocks, shores of Straits of Magellan, accompanying (in the specimen) *Buellia petræa b. vulgaris* and *B. geographica*, *Rev. T. Hill* (Hassler exp. 1872). The lichen itself not a little resembles *B. stellulata* (Tayl.).

Lecidea tessellina, sp. nov.: thallo rimoso-areolato glaucescente (cinerascente vel dein sublutescente) areolis planis lævigatisque (rarius turgidis) hypothallo atro subinde marginatis; apotheciis minutis (latit. 0,3-07 mm.) areolis immersis e concavo mox planis nudis, margine tenui acuto subpersistente, demum confluenti-difformibus. Hypothecium incolor. Sporæ octonæ, ellipsoideæ, simplices, incolores, longit. 0,009-14$^{mm.}$, crassit. 0,005-7$^{mm.}$, paraphysibus coalitis. — Common on various rocks throughout the Appalachian range, and observed also westward, in Kansas and Missouri, by *E. Hall*. A well-marked lichen, which I long tried to consider a lecideoid *Lecanora* (§ *Aspicilia*), with which group it accords, moreover, in its spermogones and staff-shaped spermatia on subsimple sterigmas. The reaction of the thallus with K is yellow (becoming in time reddish), and that of the hymeneal gelatine with iodine, blue.

Lecidea cyrtidia, sp. nov.: thallo effuso tenuissimo leproso olivaceo-virente; apotheciis perminutis (latit. 0,2-0,4 mm.) appressis mox convexis immarginatisque. Hypothecium nigrum. Sporæ 6-8^{nae} ovoideo-ellipsoideæ, simplices nebulosæ vel pseudo-biloculares, incolores, longit. 0,006-10$^{mm.}$, crassit. 0,0025-45$^{mm.}$, paraphysibus coalitis. — On sandstone, Missouri, *E. Hall*; Pebbles, Quincy, Mass., *H. Willey*. A very humble, but yet marked, lichen.

APPENDIX.

Kerguelen Lichens. A brief notice of lichens collected in Kerguelen's Land by Dr. Kidder, Naturalist of the United States Transit Expedition in 1874–75, as of a few others gathered previously in the same island by Dr. Hooker, and now preserved in the late Dr. Thomas Taylor's herbarium (Herb. Bost. Soc. Nat. Hist.), was prepared and published by the present writer in the Bulletin of the Torrey Bot. Club, Vol. VI. No. 10 (Oct. 1875). In the November following, a note on "New Lichens from Kerguelen Land," collected by the Rev.

A. E. Eaton, of the British Transit Expedition, and determined by Dr. Nylander, was published by the Rev. J. M. Crombie in the "Journal of Botany," and was followed by a full enumeration of Mr. Eaton's lichens by the same gentleman, with the same assistance, in the "Journal of the London Linnæan Society, Vol. XV.; as now, at length, by a "Revision of the Kerguelen Lichens collected by Dr. Hooker," in the "Journal of Botany," for April, 1877. The naturalist of the British expedition had much better luck in collecting, amid the countless discouragements of the "island of desolation," or was less embarrassed by other and higher branches of natural history, than ours; and Messrs. Nylander and Crombie have thus been able to largely extend this curious lichen-flora; while a comparison with Dr. Hooker's specimens (very few, indeed, of which could be discovered in the herbarium of Dr. Taylor) has enabled them to determine some of the latter writer's new species, for the determination of which his own descriptions were entirely inadequate. There is also something over a page, in Mr. Crombie's last paper, of observations on the present writer's list of Kerguelen lichens above mentioned, upon which it will be proper to make some remarks.

And first as to what is called the unfortunate "neglect of the chemical reactions," which, it is said, renders the "diagnosis incomplete, and so far uncertain." This is simply a matter of opinion. I studied the question of the use of certain chemicals in the systematic investigation of lichens, with such care as I could give it, ten years ago, and have since seen no reason to change the view then expressed (Amer. Naturalist, April, 1868). The application to the lichen-tissues of the tests used is not without interest, and may give results of some utility, *so far at least as they go;* but this *quantum videtur* impedes every stage of the inquiry, and the unequivocal value assumed for the results has never been any thing but an assumption. And opinions may also differ as to the value of the chemical "species" which have resulted from the "reactions." Dr. Nylander has remarked of one of these species, his *Parmelia cetrarioides,* that it scarcely differs from another except chemically, — "*vix differt nisi reactione. . . . a P. olivetorum: at distinguenda est nomine proprio, jam eam ob causam*" (Nyl. *Obs. Lich. Pyr. Orient.* p. 16), and his remark is applicable to not a few others, whether or not now appearing to be supported by secondary lichen-characters. I decline, for my part, to receive such species. And there can be no doubt that the tendency of this scrutiny of "the reactions," as of another now far from unknown method of study, — the scrutiny, that is, of minute and not seldom unimportant differences of all sorts, to the ignoring, for

the time at least (whatever may be intended in the future), of the more difficult and important consideration in full of the points of agreement with known forms, — is simply to minimize the value of species; and can have but one result, and that only a disastrous one, on the future of Lichenology.

Usnea sulphurea (Müll.), Th. Fr., is the same certainly as *Neuropogon melaxanthus* (Ach.) Nyl. But it is not questioned that the lichen named is indigenous to both the Arctic and Antarctic zones, and was first published from the former under the name first cited above. The fact that the Arctic condition is less luxuriant than the other can make no difference in the application of the universally recognized rule of nomenclature, which overrides individual preferences, and is intended to. But my reviewer continues that "Tuckerman also seems to imply that *Neuropogon Taylori* (Hook. fil.) cannot rightly be discriminated from the preceding." It was, perhaps, rather more than implied. Having, for many years, been in receipt of specimens of the yellow *Usnea* of the polar regions, especially of the antarctic forms, it became a matter of some interest to me to determine the *U. Taylori*, considered (it should appear) by Dr. Taylor to take the place, in Kerguelen's Land, of the older species; but not likely to be restricted to the island. The endeavor was in vain, and even in Dr. Kidder's large Kerguelen collection there was nothing that appeared separable from the plant of the Falkland Islands, as there was nothing in either Taylor's or Nylander's diagnosis of *U. Taylori* satisfactorily to distinguish it.

Pannaria Taylori, Tuckerm. *ubi sup.*, Oct. 1875, which was described from a specimen without name in the Taylor herbarium, is the same, it fully appears, as the *P. placodiopsis*, Nyl., of the "Journal of Botany," of November of the same year. But Mr. Crombie is now able to show, from Dr. Hooker's specimen, that the lichen is *Lecanora dichroa*, Tayl., which would hardly be guessed from the description. That certainly seems to indicate an areolate, only sub-effigurate plant, of much the type of *Lecanora gelida*; and by no means this marked *Pannaria*.

"*Pannaria glaucella*, Tuck., sp. n. = *Amphidium molybdoplacum*, Nyl." I cite this definite statement as it stands in Mr. Crombie's paper. It seems, however, from the evidence of the same gentleman, that there is no doubt at all that the plant is new; or that it was published by one writer, under the specific name *glaucella* in October, and by another under that of *molybdoplaca*, in the following November. This should appear to settle the name of the species; but what of the genus, and where is it defined? The only reference to it that I can discover is in

Dr. Nylander's *Obs. Lich. in Pyren.* 1873, p. 48, where a "*Leptogium* (*Amphidium*) *terrenum*" is described, and the remark immediately follows, that this new *Leptogium* of the new section *Amphidium* is really to be taken for a new genus, — "*genus novum quoad thallum, quasi Pannaria . . . sed sporæ solitæ Leptogii . . . Genus Amphidium nondum satis cognitum.*" But the *Amphidium* of Kerguelen's Land differs considerably from the Pyrenean one, and the proposed genus seems as far from establishment as ever. In his full diagnosis of the species in Mr. Crombie's "Enumeration of Kerguelen Lichens," cited above, Dr. Nylander compares it with *Pannaria elæina.* I must still consider the affinity of the plant Pannariine and not Collemeine, and continue to call it *Pannaria glaucella.*

Placodium bicolor, Tuckerm. *ubi sup.*, is, without doubt, correctly referred by Messrs. Nylander and Crombie to *Lecanora gelida*, v. *lateritia*, Nyl. I had myself remarked that my plant was the same with the red *L. gelida* of Taylor's herbarium, upon which, doubtless, Nylander founded his *Squamaria lateritia* (*Énum. Gén. Lich.*), but the color suggested *Placodium*, and the spores seemed to look the same way. The polar-bilocular type (which is hardly well named "placodiomorphous") is, indeed, a very distinct one; but its exhibition in nature, if we limit groups rather by the sum of their characters than by any particular character, is now far enough from distinct.

"*Urceolina Kergueliensis* *. Tuck., *n. gen. & sp.* = *Lecanora Kerguelensis* (Tuck.)." I cite once more from Mr. Crombie's revision; and can but repeat here, in reply to Dr. Nylander's criticism, what I said at first: "the lichen is not referable to *Lecanora* § *Aspicilia*, and is excluded by its exciple from § *Squamaria;*" as, of course, from the section represented by *L. subfusca.* The apothecium certainly carries the plant into the *Urceolariei*, as these have been understood, and is irreconcilable with the Lecanorine type. It is true that Nylander has not recognized this sub-family, referring, from the first, *Gyalecta* to *Lecidea*, Nyl., and proposing to unite even *Urceolaria* with *Lecanora* (in fact, *U. scruposa* really appears as *Lecanora* (*Urceolaria*) *scruposa*, Ach., Nyl., in Norrlin *Berättelse* in *Not. Sälsk. p. F. & Fl. Förh.*, 13, 1873); but the latter of these emendations of the system is now given

* A better word, perhaps, than either *Kerguelensis*, which Messrs. Nylander and Crombie have taken leave to substitute for it in the cited paper, or *Kerguelena*, which they elsewhere employ. It is formed from *Kerguelia*, an attempt at a short latinization of the land or island of Kerguelen. *Kerguelenia* may be more correct, and *Kerguelenienis;* but hardly *Kerguela.*

up, and the former should appear to be also, as the learned author has of late described new species of *Gyalecta* (*Add. nov.* in Flora Ratisb. 1875, 1876), though without any indication of his present opinion of the limits and place of the genus. Possibly, then, the new Urceolarii-form genus from Kerguelen's Land may hereafter come into favor.

To this it is only necessary to add that the fragment of rock upon which apothecia of *Buellia parasema*, as I certainly considered them, appeared, is no longer within reach. Dr. Nylander is of opinion that they are "probably to be referred to" the closely related *B. myriocarpa*, which he has recognized on other fragments. But the former is a cosmopolitan lichen, and may well occur also.

XVI.

THEORY OF THE HORIZONTAL PHOTOHELIOGRAPH,

INCLUDING ITS APPLICATION TO THE DETERMINATION OF THE SOLAR PARALLAX BY MEANS OF TRANSITS OF VENUS.

By Professor William Harkness, U. S. Navy.

Presented March 15th, 1877.

The term "Horizontal Photoheliograph" is used to designate that form of Photoheliograph which, it is believed, was first employed by the late Professor Joseph Winlock; and which consists essentially of a fixed telescope whose optical axis is accurately horizontal and in the meridian, and whose objective is directed toward the same side of the zenith as the elevated pole; the sun's rays being reflected into the telescope by a suitable heliostat. The sensitive plate for the reception of the photographic image, is, of course, situated at the chemical focus of the telescope; the plane of the plate being perpendicular to, and its centre coinciding with, the optical axis of the telescope.

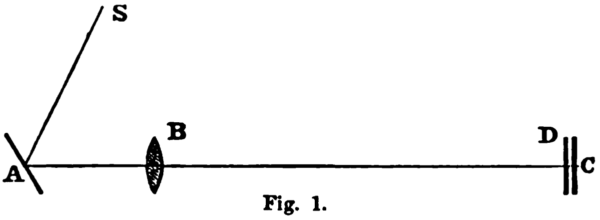

Fig. 1.

The details of the construction of the horizontal photoheliograph, in so far as they are necessary for a proper understanding of the theory of the instrument, are shown in Fig. 1.

A is the heliostat mirror, consisting of a piece of highly polished, but unsilvered glass, whose two surfaces make an angle of about sixty minutes with each other. The front surface is worked as truly plane as possible, and serves to reflect the solar rays through the objective, to the photographic plate. In working the back surface no particular pains are taken, and, on account of its inclination to the

front surface, any light reflected from it is thrown entirely away from the photographic plate. B is the objective, which is corrected for the chemical, and not for the visual rays. The distance between the objective and mirror is made as small as possible, consistently with keeping the latter clear of the shadow of the former. D is the reticule, the construction and use of which will be explained presently. C is the photographic plate, the sensitive surface of which faces the objective. The rays from the sun S are reflected by the mirror A through the objective B, and after traversing the reticule D they form an image upon the photographic plate C.

The reticule consists of a system of squares, formed by the intersection of two systems of very fine, straight lines, which are drawn upon one side of, and respectively parallel to the edges of, a thin, square plate of plano-parallel glass; as shown in Fig. 2. In each of these linear systems the number of lines is odd, and the middle line is drawn through the centre of the plate. This reticule is fixed at D, Fig. 1, with its ruled surface toward, parallel to, and two or three millimeters distant from, the sensitive surface of the plate C. Moreover, one of the two systems of lines is set as nearly as possible vertical, and its inclination is accurately determined; and as an additional safeguard, a plumb line, consisting of a silver wire about 0.05 of a millimeter in diameter, is suspended between the reticule and the photographic plate, in such a position that it may hang freely, and at the same time be very nearly in the vertical plane passing through the centres of the reticule and objective. As the light from the objective traverses the reticule before it reaches the photographic plate, the shadow, both of the reticule and of the plumb line, is impressed upon every picture taken with the apparatus; and thus three different ends are gained: Firstly, by comparing the squares of the reticule with the corresponding ones upon the picture, every thing relating to the shrinkage of the collodion can be determined; secondly, the impression of the plumb-line, and also that of the vertical lines, furnishes upon each picture a fixed direction from which to measure angles of position; and, thirdly, the intersection of the middle vertical with the middle horizontal line furnishes a fixed point, which will hereafter be designated as the centre of the

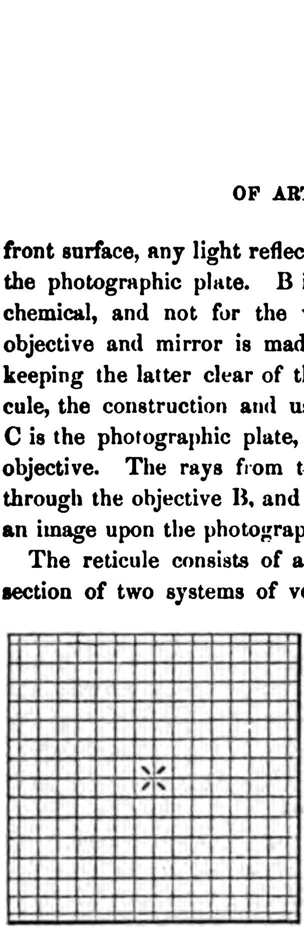

Fig. 2.

plate. To determine the zenith distance and azimuth of this point it is necessary to measure the zenith distance and azimuth of the corresponding point of the reticule, as seen from the second principal point of the objective. For that purpose the mirror A, Fig. 1, is temporarily removed, and a transit instrument is set up in front of the objective B, and in the prolongation of its axis. The objective thus becomes a collimator to the transit instrument, through the eyepiece of which the lines of the reticule may be observed as if they were at an infinite distance. It should be remarked, however, that, as the reticule is slightly inside the visual focus of the objective, it is not generally possible to obtain perfectly distinct vision of its lines and of the wires of the transit at the same time. This difficulty is obviated by marking the intersection of the middle vertical and middle horizontal lines of the reticule in such a distinct manner that the slight mal-adjustment of focus does not prevent it from being seen. Then, by means of the transit, the reticule is adjusted so that the point in question is very approximately in the meridian, and at a zenith distance of ninety degrees. Finally, the exact azimuth and zenith distance of the point are measured.

If the photoheliograph is employed to depict any object whose linear magnitude is such that it subtends an angle a at the first principal point of the objective, and if the centre of the image coincides with the centre of the plate upon which it is taken; then, no matter what may be the solar focal distance of the objective, the magnitude of the image will be

$$2 \tan \tfrac{1}{2}a \, (D + E'' - T) \qquad (1)$$

where D is the distance between the back surface of the objective and the sensitive surface of the photographic plates, E'' the distance from the back surface of the objective to its second principal point; and T a correction due to the thickness of the reticule plate. It is thus evident that, in all calculations involving measurements of pictures taken with this apparatus, the value to be employed as the focal distance of the objective is

$$D + E'' - T \qquad (2)$$

D is obtained by direct measurement, the accuracy of which must be such that the uncertainty of the resulting value will not exceed one part in ten thousand, and it is desirable that it should not exceed one part in forty thousand. To obtain E'' we put

n = refractive index of crown-glass lens.
n' = refractive index of flint-glass lens.

ne	= thickness of crown-glass lens.
$n'e'$	= thickness of flint-glass lens.
s	= space between the interior surfaces of the crown and flint lenses, measured along the optical axis.
$(n-1)f'$	= radius of first surface of crown lens. N. B. — This is the surface nearest the heliostat.
$(n-1)f''$	= radius of second surface of crown lens.
$(n'-1)f'''$	= radius of first surface of flint lens.
$(n'-1)f^{\text{iv}}$	= radius of second surface of flint lens.
φ°	= focal distance of crown-glass lens.
φ'	= focal distance of flint-glass lens.

Then, from the "Dioptrische Untersuchungen" given in "Gauss' Werke," Vol. 5, pp. 262–265, we derive the formulæ

$$\varphi^\circ = \frac{f'f''}{f'+f''-e} \qquad \varphi' = \frac{f'''f^{\text{iv}}}{f'''+f^{\text{iv}}-e'} \tag{3}$$

And if the objective is an ordinary double achromatic, corrected either for the visual or chemical rays,

$$\left.\begin{aligned} t' &= s + \frac{e\varphi^\circ}{f'} + \frac{e'\varphi'}{f^{\text{iv}}} \\ E'' &= \varphi' \left\{\frac{e'}{f'''} + \frac{t'}{\varphi^\circ + \varphi' - t'}\right\} \end{aligned}\right\} \tag{4}$$

But if it is a single lens, then

$$E'' = \frac{e\varphi^\circ}{f'} \tag{5}$$

To find the value of the correction T, let $abcd$, Fig. 3, be a section of the reticule plate, and let ef be a ray of light incident upon it in the plane of the paper. If this ray suffered no refraction, it would emerge from the plate at g; but, owing to refraction, it actually does emerge at h, after which its path is parallel to ef produced. At h erect a perpendicular to bc. It will be intersected at i by ef produced, and the distance hi will be the required value of T. Let t be the thickness of the glass composing the reticule plate; n its index of refraction; and i the angle of incidence of the ray ef. Then

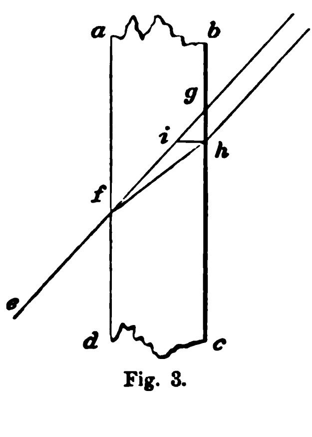

Fig. 3.

$$T = \frac{t(n-1)\cos i}{n} \tag{6}$$

and as i cannot exceed half a degree, its cosine will be very nearly unity, and it will be sufficiently accurate to write

$$T = \frac{t(n-1)}{n} \tag{7}$$

If we assume the reticule plate to be of crown glass, and its refractive index to be 1.53, then $T = 0.347\,t$; and it is evident that, in order to make T small, the reticule plate should be as thin as possible.

From the experience thus far had with the horizontal photoheliograph, it appears that, if the focal distance of the objective is F, its clear aperture should be $0.0100\,F$. The clear aperture of the heliostat mirror, which is circular in form, should be $0.0142\,F$. The plates upon which the pictures are taken should be square, and of such a size that their sides, as seen from the centre of the objective, may subtend an angle of about sixty minutes. This should also be the size of the reticule plate, and the distance between any two consecutive lines of the reticule should subtend an angle of about four minutes. Throughout the remainder of this paper it will be assumed that these are the proportions of the apparatus. The actual focal distance of the objectives of the instruments heretofore constructed has generally been about twelve meters.

To avoid repetition, the notation which will be employed throughout the remainder of this paper is here given. Let PA, Fig. 4, be the meridian of the place of observation; P being the pole, and Z the zenith. Let S be the position of the sun as seen from the centre of the earth, and S_* its position as seen from the place of observation. Hereafter, to avoid circumlocution, S will be designated as the true, and S_* as the apparent, sun. Let v be the vertex of the apparent sun, and V the position of Venus as seen from the centre of the earth. Also, let M be the point where the normal to the heliostat mirror pierces the heavens, and V', S', S'_*, and v', the positions of the reflected images of Venus, the true sun, the apparent sun, and the vertex of the apparent sun, as seen from the second principal point of the photographic objective. Then the following notation will be adopted:—

φ = latitude of the place of observation.
φ' = co-latitude of the place of observation = PZ = $90° - \varphi$.
Δ_s = polar distance of true sun = PS.

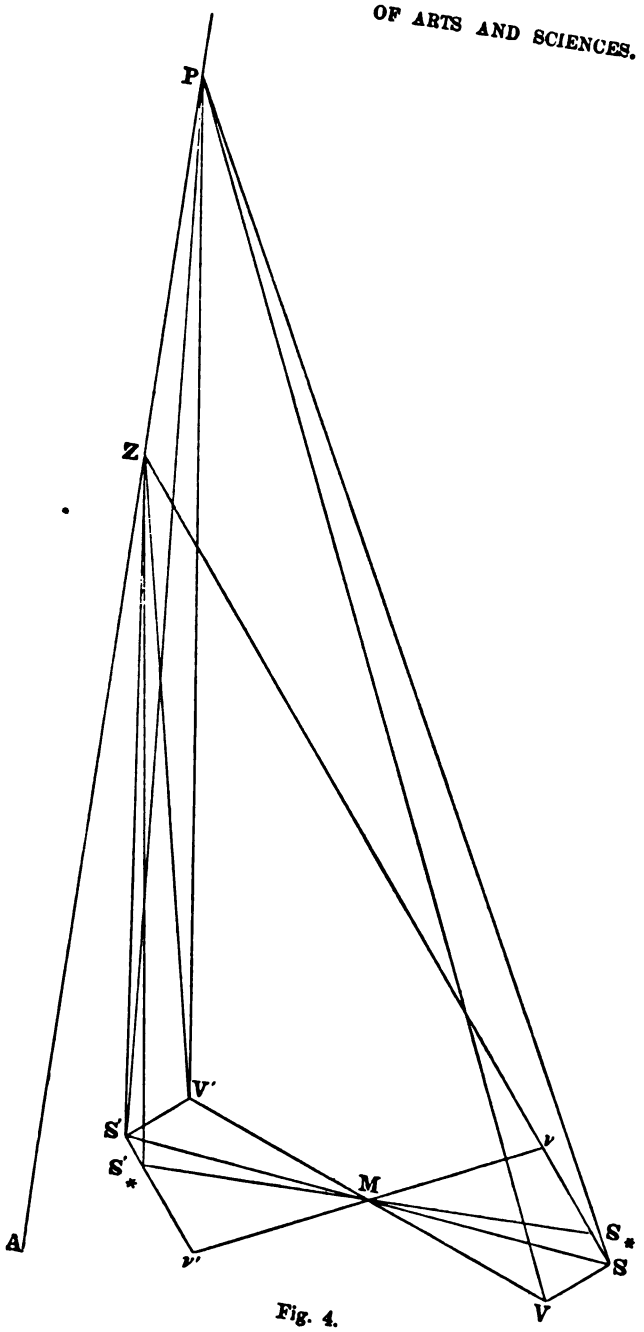

Fig. 4.

Δ_v = polar distance of Venus = PV.
Δ'_s = polar distance of the reflected image of the true sun = PS′.
Δ'_v = polar distance of the reflected image of Venus = PV′.
t_s = hour angle of true sun = APS.
t_v = hour angle of Venus = APV.
t'_s = hour angle of the reflected image of the true sun = APS′.
t'_v = hour angle of the reflected image of Venus = APV′.
ζ_s = zenith distance of true sun = ZS.
ζ'_s = zenith distance of the reflected image of the true sun = ZS′.
ζ''_s = zenith distance of the reflected image of the apparent sun = ZS'_*.
ζ'_v = zenith distance of the reflected image of Venus = ZV′.
A_s = azimuth of the true sun = AZS.
A'_s = azimuth of the reflected image of the true sun = AZS′.
A''_s = azimuth of the reflected image of the apparent sun = AZS'_*.
A'_v = azimuth of the reflected image of Venus = AZV′.
θ = the angle ZS'_*S'.
r = the refraction.
π' = the parallax in altitude. Hence $r - \pi' = SS_* = S'S'_*$.
β = the angle ZS′V′.
γ = the angle ZV′S′.
λ = the angle PS′V′.
ρ = the geocentric distance from centre of sun to centre of Venus = S V′ = SV.
ω = the geocentric position angle of Venus relatively to the sun's centre = PSV.
σ = the angle PVS.
χ = the angle PSS′.
ψ = the angle PS′S.

We have next to show how pictures obtained with the horizontal photoheliograph may be measured, and the results expressed in terms of some one of the systems of spherical co-ordinates usually employed in astronomy.

Upon an engine arranged to give polar co-ordinates, the plate to be measured is carefully adjusted, so that the centre of the image of the sun coincides as accurately as possible with the origin of co-ordinates. The fixed line, from which the angles of the co-ordinates are to be measured, is taken perpendicular to the image of the plumb line; the zero being toward that edge of the plate which was on the right hand, as viewed from the object glass, when the picture was taken, and (the

collodion side of the plate being nearest the observer) a motion of the radius vector in the opposite direction to that of the hands of a watch corresponding to increasing angles. Then the distance from the origin of co-ordinates to the sun's limb is measured at every thirty degrees, throughout the whole circumference; and the distances and angles to the centre of Venus, and to the centre of the plate, are also measured.

Owing to the effect of refraction, the outline of the sun's image will not be circular, but may, with sufficient accuracy, be assumed to be an ellipse whose minor axis coincides with the vertical circle passing through the sun's centre. To find the position of the image of this vertical circle upon the photographic plate, we refer to Fig. 4; and remark that, owing to the equality of the angles of incidence and reflection, $S_*M = S'_*M$, $vM = v'M$, and the angle S_*Mv is equal to the angle S'_*Mv'. Hence $vS_*S'_* = S_*S'_*v'$, and $ZS'_*v' = ZS'_*S_* + S_*S'_*v' = ZS'_*S_* + ZS_*S'_*$. But ZS'_* is the direction of the plumb line upon the plate, and S'_*v' is the semi-minor axis of the elliptical image of the sun. To find the value of the angle ZS'_*v' we require the zenith distance and azimuth of the true sun, which are given by the formulæ (8); the necessary data being, the exact instant at which the picture was taken, the right ascension and polar distance of the sun, and the latitude of the place of observation.

$$\left.\begin{aligned} \tan M &= \frac{\cot \Delta_s}{\cos t_s} \\ \tan A_s &= \frac{\tan t_s \cos M}{\sin (\phi - M)} \\ \tan \zeta_s &= \frac{\tan (\phi - M)}{\cos A_s} \end{aligned}\right\} \qquad (8)$$

The zenith distance, ζ''_s, and azimuth A''_s, of the reflected image of the apparent sun, are found by methods explained in a subsequent part of this paper. Then, in the spherical triangle $ZS_*S'_*$, the angle $S_*ZS'_*$ is equal to $A_s \sim A''_s$, $ZS'_* = \zeta''_s$, and $ZS_* = \zeta_s - r + \pi'$, where r and π' are the refraction, and parallax in altitude. Whence, putting the angle $ZS'_*v' = 180^\circ - \theta$,

$$\cot \tfrac{1}{2}\theta = \frac{\cos \frac{1}{2}(\zeta''_s - \zeta_s + r - \pi')}{\cos \frac{1}{2}(\zeta''_s + \zeta_s - r + \pi')} \cot \tfrac{1}{2}(A_s \sim A''_s) \qquad (9)$$

Thus the angle upon the photographic plate, between the fixed line of reference and the major axis of the image of the apparent sun, will

be θ; and if R and ε are the polar co-ordinates of any point of the limb of this image, its rectangular co-ordinates, referred to its axes and approximate centre will be

$$\left.\begin{aligned} y' &= R \sin (\varepsilon \mp \theta) \\ x' &= R \cos (\varepsilon \mp \theta) \end{aligned}\right\} \qquad (10)$$

in which the upper signs are to be taken when the sun is west, and the lower when it is east, of the meridian.

Owing to atmospheric disturbances, the image of the sun's limb will generally be more or less irregular, and no matter how carefully it may be centred on the measuring engine, the point from which the measures are made will seldom coincide quite accurately with the centre of the image. On this account, to obtain the co-ordinates of any point of the limb referred rigorously to the centre and axes, the equations (10) must be corrected by the small quantities δy and δx, and thus we get

$$\left.\begin{aligned} y &= R \sin (\varepsilon \mp \theta) + \delta y \\ x &= R \cos (\varepsilon \mp \theta) + \delta x \end{aligned}\right\} \qquad (11)$$

The image of the sun's limb being taken as an ellipse, its equation will be

$$0 = -A^2B^2 + A^2y^2 + B^2x^2 \qquad (12)$$

where A and B are respectively the horizontal and vertical semi-diameters of the sun, affected by refraction and parallax. Putting $B^2 = nA^2$, substituting this value in equation (12), and dividing by A^2, we get

$$0 = -nA^2 + y^2 + nx^2 \qquad (13)$$

Finally, substituting the values of y and x from the equations (11), neglecting the squares of δy and δx, and reducing, we obtain

$$0 = \left\{\begin{aligned} &+ \tfrac{1}{2}\left[\sin^2 (\varepsilon \mp \theta) + n \cos^2 (\varepsilon \mp \theta)\right] R \\ &- \frac{n}{2R} A^2 + \sin (\varepsilon \mp \theta)\, \delta y \\ &+ n \cos (\varepsilon \mp \theta)\, \delta x \end{aligned}\right\} \qquad (14)$$

Each measurement of the sun's limb, made upon the photograph, gives one equation of the form (14), and from all the equations thus

obtained the values of A, δy, and δx are found by the method of least squares.

The contraction of the sun's vertical semi-diameter on account of refraction will be $\frac{1}{2}(r' - r'')$; where r' and r'' are respectively the refraction of the lower and upper limbs. The contraction of the horizontal semi-diameter on account of refraction, for all zenith distances less than 85°, may be taken as constant and equal to $0''.25$. Hence, if s represents the sun's semi-diameter, we have

$$n = \left(\frac{s - \frac{1}{2}(r' - r'')}{s - 0''.25}\right)^2 \qquad (15)$$

which is the value to be employed in equation (14).

As changes of refraction are not strictly proportional to changes of zenith distance, the centre of the sun's image will not coincide rigorously with the image of the sun's centre. Let the distance between those two points be δr, and let r''' be the refraction of the sun's centre, r'' and r' being respectively the refraction of his upper and lower limbs, as before. Then

$$\delta r = \tfrac{1}{2}(r' + r'') - r''' \qquad (16)$$

and the co-ordinates of the image of the sun's centre are $\delta y + \delta r$, and δx. These rectangular co-ordinates are transformed into polar co-ordinates of our original system by means of the formulæ

$$\left.\begin{aligned} R &= [(\delta y + \delta r)^2 + (\delta x)^2]^{\frac{1}{2}} \\ \sin\eta &= \frac{\delta y + \delta r}{R} \\ \cos\eta &= \frac{\delta x}{R} \\ \varepsilon &= \eta \pm \theta \end{aligned}\right\} \qquad (17)$$

where the double sign is to be taken in the same way as in equations (10).

The polar co-ordinates of the image of the centre of the apparent sun have thus been found; and our original measurements gave the polar co-ordinates of the centres of the image of the apparent Venus and of the photographic plate. Let R, R', R'' be, respectively, the radii vectores, and ε, ε', ε'' the angles of these co-ordinates. Passing now to a system of rectangular co-ordinates whose origin is at the centre of the plate, and whose axis of X is parallel to the fixed

line of the original system of polar co-ordinates; we get for the image of the centre of the apparent sun,

$$\left.\begin{aligned} y &= R \sin \varepsilon - R'' \sin \varepsilon'' \\ x &= R \cos \varepsilon - R'' \cos \varepsilon'' \end{aligned}\right\} \qquad (18)$$

and for the image of the centre of the apparent Venus

$$\left.\begin{aligned} y' &= R' \sin \varepsilon' - R'' \sin \varepsilon'' \\ x' &= R' \cos \varepsilon' - R'' \cos \varepsilon'' \end{aligned}\right\} \qquad (19)$$

Let it be assumed that when the picture was taken ζ_0 and A_0 were the zenith distance and azimuth of the centre of the plate, as seen from the second principal point of the objective; and that F was the reduced distance between the latter point and the sensitive surface of the plate, or in other words,

$$F = D + E'' - T \qquad (20)$$

as given by equation (2). Further, let the angles subtended at the second principal point of the objective by the co-ordinates, y, x, y', x', of the equations (18) and (19) be, respectively, $\delta\zeta_s$, δA_s, $\delta\zeta_v$, δA_v. Then, as the plate was perpendicular to, and its centre coincided with, the optical axis of the objective,

$$\left.\begin{aligned} \tan \delta\zeta_s &= \frac{R \sin \epsilon - R'' \sin \epsilon''}{F} \\ \tan \delta A_s &= \frac{R \cos \epsilon - R'' \cos \epsilon''}{F} \\ \tan \delta\zeta_v &= \frac{R' \sin \epsilon' - R'' \sin \epsilon''}{F} \\ \tan \delta A_v &= \frac{R' \cos \epsilon' - R'' \cos \epsilon''}{F} \end{aligned}\right\} \qquad (21)$$

Denoting by ζ'_s, A''_s, ζ'_v, A''_v the apparent zenith distances and azimuths of the reflected images of the sun and Venus, as seen from the second principal point of the objective, we now have

$$\left.\begin{aligned} \zeta'_s &= \zeta_0 - \delta\zeta_s \\ A''_s &= A_0 + \delta A_s \\ \zeta'_v &= \zeta_0 - \delta\zeta_v \\ A''_v &= A_0 + \delta A_v \end{aligned}\right\} \qquad (22)$$

The next step will be to free these zenith distances and azimuths from the effects of refraction and parallax. For that purpose, consider the spherical triangle $ZS'S'_*$, Fig. 4; but instead of limiting the points S, S_*, S', S'_*, to the sun, let them represent any heavenly body whatever. Then, $ZS' = \zeta'$; $ZS'_* = \zeta''$; $S'S'_* = SS_* = r - \pi'$; $S'ZS'_* = A'' \sim A'$; and $ZS'_*S' = \theta$, the value of which is given by equation (9). The relations subsisting among these parts are,

$$\left.\begin{aligned} \tan m &= \tan (r - \pi') \cos \theta \\ \sin \zeta' \cos (A'' \sim A') &= \frac{\cos (r - \pi') \sin (\zeta'' - m)}{\cos m} \\ \sin \zeta' \sin (A'' \sim A') &= \sin (r - \pi') \sin \theta \end{aligned}\right\} \qquad (23)$$

To simplify these equations we remark that $(r - \pi')$ will rarely amount to 5′, and as $\cos \theta$ must always be less than unity, we may write with all needful accuracy

$$m = (r - \pi') \cos \theta \qquad (24)$$

ζ' will never differ from 90° by so much as 30′, and therefore its sine may be taken as unity; while as $(A'' \sim A')$ can scarcely amount to 5′, and will usually be far less, we may write unity for its cosine, and substitute the arc for its sine. We thus find

$$\left.\begin{aligned} \zeta' &= \zeta'' - (r - \pi') \cos \theta \\ A' &= A'' \mp (r - \pi') \sin \theta \end{aligned}\right\} . \qquad (25)$$

As these equations are perfectly general, we have only to substitute in them, for ζ'' and A'', the apparent zenith distances and azimuths of the images of the sun and Venus, given by the equations (22), and there results the true zenith distances and azimuths of the images of these bodies, which are

$$\left.\begin{aligned} \zeta'_s &= \zeta_0 - \delta\zeta_s - (r_s - \pi'_s) \cos \theta_s \\ A'_s &= A_0 + \delta A_s \mp (r_s - \pi'_s) \sin \theta_s \\ \zeta'_v &= \zeta_0 - \delta\zeta_v - (r_v - \pi'_v) \cos \theta_v \\ A'_v &= A_0 + \delta A_v \mp (r_v - \pi'_v) \sin \theta_v \end{aligned}\right\} \qquad (26)$$

in which the upper signs are to be taken when the body is west, and the lower when it is east, of the meridian. Strictly speaking, the value of θ will not be the same for Venus as for the sun, but the

difference will generally be so slight that either value may be employed for both bodies.

The effect of parallax in azimuth in displacing Venus relatively to the sun's centre can never exceed 0″.08, and will usually be much less; but, if it is thought desirable to correct the equations (26) on that account, the mode of doing so will be obvious when it is remembered that it will be sufficiently accurate to consider the parallax in azimuth as acting perpendicularly to the parallax in altitude.

From the zenith distances and azimuths given by the equations (26), the corresponding polar distances and hour angles must next be found. The rigorous formulæ for this purpose are

$$\left.\begin{aligned} \tan m &= \tan \zeta' \cos A' \\ \tan t &= \frac{\tan A' \sin m}{\cos (\phi - m)} \\ \operatorname{cotan} \Delta &= \tan (\varphi - m) \cos t \end{aligned}\right\} \qquad (27)$$

but A' will generally be so small that its cosine may be taken as unity, and then we may write

$$\left.\begin{aligned} \tan t &= \frac{\tan A' \sin \zeta'}{\cos (\phi - \zeta')} \\ \operatorname{cotan} \Delta &= \tan (\varphi - \zeta') \cos t \end{aligned}\right\} \qquad (28)$$

In the spherical triangle PS′V′, Fig. 4, we have the relations

$$\left.\begin{aligned} \tan m &= \tan \Delta'_v \cos (t'_s \sim t'_v) \\ \sin \varrho \cos \lambda &= \frac{\cos \Delta'_v}{\cos m} \sin (\Delta'_s - m) \\ \sin \varrho \sin \lambda &= \sin \Delta'_v \sin (t'_s \sim t'_v) \end{aligned}\right\} \qquad (29)$$

Usually it will be sufficiently accurate to put $\cos (t'_s \sim t'_v) = 1$, and then $m = \Delta'_v$, and these equations become

$$\left.\begin{aligned} \sin \varrho \cos \lambda &= \sin (\Delta'_s - \Delta'_v) \\ \sin \varrho \sin \lambda &= \sin \Delta'_v \sin (t'_s \sim t'_v) \end{aligned}\right\} \qquad (30)$$

from which ϱ and λ are obtained. As a check, ϱ may be computed directly from the zenith distances and azimuths furnished by the equations (26), the requisite formulæ being

$$\left.\begin{aligned} \tan B &= \frac{(A'_s \sim A'_v)\sin\zeta'_s}{\zeta_v - \zeta'_s} \\ \varrho &= \frac{(A'_s \sim A'_v)\sin\zeta'_s}{\sin B} = \frac{\zeta'_v - \zeta'_s}{\cos B} \end{aligned}\right\} \quad (31)$$

From the spherical triangle PSS′, Fig. 4, we get

$$\left.\begin{aligned} \tan\tfrac{1}{2}(\chi + \psi) &= \frac{\cos\frac{1}{2}(\Delta'_s - \Delta_s)}{\cos\frac{1}{2}(\Delta'_s + \Delta_s)} \cot\tfrac{1}{2}(t'_s \sim t_s) \\ \tan\tfrac{1}{2}(\chi - \psi) &= \frac{\sin\frac{1}{2}(\Delta'_s - \Delta_s)}{\sin\frac{1}{2}(\Delta'_s + \Delta_s)} \cot\tfrac{1}{2}(t'_s \sim t_s) \end{aligned}\right\} \quad (32)$$

Referring again to Fig. 4, it is evident that SV is the distance, and PSV the position angle of Venus from the centre of the sun. To find the values of these quantities we have

$$\left.\begin{aligned} SV &= S'V' = \varrho \\ PSV &= PSS' \pm S'SV = PSS' \pm SS'V = PSS' \pm PS'S \mp PS'V' \end{aligned}\right\} \quad (33)$$

But PSV $= \omega$, PSS′ $= \chi$, PS′S $= \psi$, PS′V′ $= \lambda$, and thus we get

$$\omega = (\chi \pm \psi) \mp \lambda \qquad (34)$$

in which the upper signs are to be taken when PS′S is greater than PS′V′, and the lower when PS′S is less than PS′V′. If it is assumed that the pole which forms part of the triangle PSV is always the elevated one; and also that position angles are counted from the north around by the east; then, in the northern hemisphere, when the sun is east of the meridian the position angle will be $360° - \omega$, while west of the meridian it will be ω; and in the southern hemisphere, when the sun is east of the meridian the position angle will be $180° + \omega$, while west of the meridian it will be $180° - \omega$.

Finally, if the polar distance of Venus, and the difference between her right ascension and that of the sun are required, these quantities may be obtained from the spherical triangle PSV by means of the formulæ

$$\left.\begin{aligned} \tan n &= \tan\varrho\cos\omega \\ \tan\Delta_v\cos(\alpha_s \sim \alpha_v) &= \tan(\Delta_s - n) \\ \tan\Delta_v\sin(\alpha_s \sim \alpha_v) &= \frac{\sin n\tan\omega}{\cos(\Delta_s - n)} \end{aligned}\right\} \quad (35)$$

in which α_s and α_v are respectively the right ascensions of the sun and of Venus.

In the preceding development of the theory of the horizontal photoheliograph, continual reference has been made to the centres of the sun and Venus, but of course it will be understood that all the equations apply equally well to any other pair of celestial objects which may have been photographed with the same apparatus.

As the horizontal photoheliograph was much used in observing the last transit of Venus, it is perhaps desirable to give here a direct method of deducing the solar parallax from the photographs then obtained. For that purpose consider the quadrilateral PZS′S, which is composed of the triangles PZS′ and PS′S. In the triangle PZS′ we have the relation

$$\sin A'_s \cot B = \sin \zeta'_s \cot \varphi' + \cos \zeta'_s \cos A'_s \qquad (36)$$

in which φ' is the colatitude, ZP; and B is the angle ZS′P. Considering all the parts, except φ', as variable, and differentiating, we get

$$\left.\begin{aligned} dB = &-\frac{\sin^2 B}{\sin A'_s} \cos \zeta'_s \left(\cot \varphi' \, d\zeta'_s + \sin A'_s \, dA'_s\right) \\ &+ \cos A'_s \left(\frac{\sin^2 B}{\sin A'_s} \sin \zeta'_s \, d\zeta'_s - \frac{\sin B}{\sin A'_s} \cos B \, dA'_s\right) \end{aligned}\right\} \qquad (37)$$

To obtain approximately the maximum value of this differential, we remark that A'_s can never exceed $\pm$ 13′; and as $\sin B$ must always be less than $\sin A'_s$, $\frac{\sin B}{\sin A'_s}$ must be less than unity; and $\frac{\sin^2 B}{\sin A'_s}$ must be less than $\sin A'_s$, that is, it must be less than 0.004. ζ'_s can never differ from 90° by more than $\pm$ 13′, and therefore its sine may be taken as unity, and its cosine cannot exceed 0.004. If the latitude of the place of observation is less than 50°, φ' will be greater than 40°, and its cotangent will be less than 1.20. Substituting these values in the second member of equation (37), all the terms except the last become evanescent, and we may write, without an error of one part in ten thousand,

$$dB = -\, dA'_s \qquad (38)$$

But the only way in which A'_s can be made to vary is by varying the adopted value of the solar parallax, π_s. Hence, as ZS′ is nearly 90°, dA'_s is the resolved value of $d\pi_s$, and as it can never exceed that quantity, it is safe to write

$$dB = -\, d\pi_s \qquad (39)$$

In the triangle PSS′ we have the relations

$$\left.\begin{aligned}\cos\chi &= -\cos\psi\cos(t_s \sim t'_s) + \sin\psi\sin(t_s \sim t'_s)\cos\Delta_s \\ \cos\psi &= -\cos\chi\cos(t_s \sim t'_s) + \sin\chi\sin(t_s \sim t'_s)\cos\Delta'_s\end{aligned}\right\}\quad(40)$$

Considering all the parts as variable, differentiating, and reducing, we get

$$\left.\begin{aligned}d\chi &= \sin\Delta'_s\sin(t_s \sim t'_s)\,d\Delta_s - \cos\Delta'_s\,d(t_s \sim t'_s) - \cos SS'\,d\psi \\ d\psi &= \sin\Delta_s\sin(t_s \sim t'_s)\,d\Delta'_s - \cos\Delta_s\,d(t_s \sim t'_s) - \cos SS'\,d\chi\end{aligned}\right\}\quad(41)$$

Adding, this becomes

$$d\chi + d\psi = \frac{\sin(t_s \sim t'_s)(\sin\Delta_s d\Delta'_s + \sin\Delta'_s d\Delta_s) - d(t_s \sim t'_s)(\cos\Delta_s + \cos\Delta'_s)}{1 + \cos SS'}\quad(42)$$

To obtain approximately the maximum value of this differential, we remark that at the time of the transit the sun's north polar distance was 112° 49′, and therefore $\sin\Delta_s = 0.922$, and $\cos\Delta_s = 0.388$. If the latitude of the place of observation is not greater than 50°, the value of Δ'_s will lie between 130° and 180°; and consequently its sine will not exceed 0.766, and its cosine cannot be greater than unity. Sin $(t_s \sim t'_s)$ cannot exceed unity. Further, as the triangle PSS′ can only be varied by varying the assumed value of the solar parallax,* $d\Delta_s$ and $d\Delta'_s$ are the resolved values, and $d\,(t_s \sim t'_s)$ is the sum of two resolved values of $d\pi_s$. It is therefore certain that $d\Delta_s$ and $d\Delta'_s$ are not greater than $d\pi_s$, and that $d\,(t_s \sim t'_s)$ is not greater than $2\,d\pi_s$. Substituting these values in equation (42), and adding all the terms, without regard to sign, we get

$$d\chi + d\psi = \frac{4\tfrac{1}{2}\,d\pi_s}{1 + \cos SS'}\quad(43)$$

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* Strictly speaking, although the point S′ can only be varied by varying the assumed value of the solar parallax, the point S can be varied, not only in that way, but also by varying the tabular place of the sun. In practice it will probably be best to neglect at first the errors of the solar tables, and afterwards, when they become known from the solution of the final equations, to compute rigorously the value of $d\chi + d\psi$ for each photograph, by means of (42), and in all cases where it exceeds two or three seconds, which will rarely happen, the corresponding conditional equations of the form of (55) and (56) may be corrected so as to accord with the new values of the solar elements, and a second solution will give very accurate results.

Hence if SS′ does not exceed 120° the value of $d\chi + d\psi$ cannot be so great as $9\, d\pi_i$. Adding to this the value of dB, from equation (39), we find that, under the circumstances specified above, the total variation of the sum of the angles ZS′S and PSS′ cannot be so great as $10\, d\pi_r$. But it is not possible that the value of the solar parallax now generally adopted can be in error by so much as 0″.2, and therefore the value of $10\, d\pi_s$ cannot be so great as 2″ and will probably be less than 1″.

Referring to the figure, it is evident that

$$\text{ZS}'\text{V}' + \text{PSV} = \text{ZS}'\text{S} + \text{PSS}' \quad \text{or}$$

$$\beta + \omega = \text{ZS}'\text{S} + \text{PSS}' \qquad (44)$$

As the angle β must be obtained from measurements made upon a photograph, it is not probable that it can be depended upon to within 5″. It has just been shown that the right-hand member of (44) will not be vitiated so much as 2″ by any possible error in the adopted value of the solar parallax. It therefore follows that the left-hand member of (44) may be regarded as constant, within the limits of error of observation, and thus it appears that

$$-\, d\beta = d\omega \qquad (45)$$

In the triangle ZS′V′ we have

$$\left.\begin{aligned} \tan \tfrac{1}{2}(\beta + \gamma) &= \frac{\cos \frac{1}{2}(\zeta_v - \zeta_s)}{\cos \frac{1}{2}(\zeta_v + \zeta_s)} \cot \tfrac{1}{2}(A'_s \sim A'_v) \\ \tan \tfrac{1}{2}(\beta - \gamma) &= \frac{\sin \frac{1}{2}(\zeta_v - \zeta_s)}{\sin \frac{1}{2}(\zeta_v + \zeta_s)} \cot \tfrac{1}{2}(A'_s \sim A'_v) \end{aligned}\right\} \qquad (46)$$

from which β and γ are derived. In the same triangle we also have the relations

$$\left.\begin{aligned} \cos \varrho &= \cos \zeta_v \cos \zeta_s + \sin \zeta_v \sin \zeta_s \cos (A'_s \sim A'_v) \\ \sin (A'_s \sim A'_v) \cot \beta &= \sin \zeta_s \cot \zeta_v - \cos (A'_s \sim A'_v) \cos \zeta_s \end{aligned}\right\} \qquad (47)$$

Considering all the parts as variable, differentiating and reducing, we find

$$\left.\begin{aligned} d\varrho &= \sin \zeta_v \sin \gamma\, d(A'_s \sim A'_v) + \cos \gamma\, d\zeta_v + \cos \beta\, d\zeta_s \\ -\sin \varrho\, d\beta &= \sin \zeta_v \cos \gamma\, d(A'_s \sim A'_v) - \sin \gamma\, d\zeta_v + \cos \varrho \sin \beta\, d\zeta_s \end{aligned}\right\} \qquad (48)$$

Reverting to the equations (26), putting $\pi'_s = M\pi_s$, $\pi'_v = N\pi_v$, $\pi_s = m\pi_v$, where π_s and π_v are respectively the equatorial horizontal parallaxes of the sun and Venus; regarding π_v as the variable, and differentiating, we get

$$\left.\begin{aligned} d\zeta'_s &= +\ mM\cos\theta_s\, d\pi_v \\ dA'_s &= \pm\ mM\sin\theta_s\, d\pi_v \\ d\zeta'_v &= +\ N\cos\theta_v\, d\pi_v \\ dA'_v &= \pm\ N\sin\theta_v\, d\pi_v \end{aligned}\right\} \quad (49)$$

Substituting these values in (48), writing unity for $\sin\zeta'_v$, θ_s for θ_v, and $d\omega$ for $-d\beta$, we obtain

$$\left.\begin{aligned} d\varrho &= \cos\theta_s\,[\pm(mM \pm N)\sin\gamma\tan\theta_s + N\cos\gamma + mM\cos\beta]\, d\pi_v \\ d\omega &= \frac{\cos\theta_s}{\sin\rho}[\pm(mM \pm N)\cos\gamma\tan\theta_s - N\sin\gamma + mM\sin\beta\cos\varrho] d\pi_v \end{aligned}\right\} (50)$$

From an ephemeris the polar distances of the sun and Venus, and the difference of their right ascensions are taken; and thus two sides and the included angle are known in the triangle PSV. The remaining parts are given by the formulæ

$$\left.\begin{aligned} \tan\mu &= \tan\Delta_v\cos(\alpha_s \sim \alpha_v) \\ \sin\varrho_0\cos\omega_0 &= \frac{\cos\Delta_v}{\cos\mu}\sin(\Delta_s - \mu) \\ \sin\varrho_0\sin\omega_0 &= \sin\Delta_v\sin(\alpha_s \sim \alpha_v) \\ \sin\varrho_0\sin\sigma &= \sin\Delta_s\sin(\alpha_s \sim \alpha_v) \end{aligned}\right\} \quad (51)$$

in which we write ϱ_0 and ω_0 to distinguish the quantities deduced from the ephemeris from the similar quantities ϱ and ω obtained from the photographs by means of the equations (30), (32), and (34).

Still considering the triangle PSV, we have the relations

$$\left.\begin{aligned} \cos\varrho_0 &= \cos\Delta_v\cos\Delta_s + \sin\Delta_v\sin\Delta_s\cos(\alpha_s \sim \alpha_v) \\ \sin(\alpha_s \sim \alpha_v)\cot\omega_0 &= \sin\Delta_s\cot\Delta_v - \cos\Delta_s\cos(\alpha_s \sim \alpha_v) \end{aligned}\right\} (52)$$

Regarding all the parts as variable, differentiating and reducing, we get

$$\left.\begin{aligned} d\varrho_0 &= \sin\Delta_v\sin\sigma d(\alpha_s \sim \alpha_v) + \cos\sigma d\Delta_v + \cos\omega_0 d\Delta_s \\ -\sin\varrho_0 d\omega_0 &= \sin\Delta_v\cos\sigma d(\alpha_s \sim \alpha_v) - \sin\sigma d\Delta_v + \cos\varrho_0\sin\omega_0 d\Delta_s \end{aligned}\right\} (53)$$

If now α_s, α_v, Δ_s, Δ_v, π_s, and π_v are the tabular values of the right ascensions, polar distances, and parallaxes of the sun and Venus; and if $\alpha_s + d\alpha_s$, $\alpha_v + d\alpha_v$, $\Delta_s + d\Delta_s$, $\Delta_v + d\Delta_v$, $\pi_s + d\pi_s$, $\pi_v + d\pi_v$, are the true values of the same quantities; then we must have

$$\left.\begin{aligned} \varrho + d\varrho &= \varrho_0 + d\varrho_0 \\ \omega + d\omega &= \omega_0 + d\omega_0 \end{aligned}\right\} \qquad (54)$$

Substituting the values of $d\varrho$, $d\varrho_0$, $d\omega$, and $d\omega_0$ from (50) and (53), we obtain finally

$$0 = \left\{\begin{aligned} &\rho_0 - \rho + \sin\Delta_v \sin\sigma\, d(\alpha_s \sim \alpha_v) + \cos\sigma\, d\Delta_v + \cos\omega_0\, d\Delta_s \\ &- \cos\theta_s\, [\pm (mM \pm N) \sin\gamma \tan\theta_s + N\cos\gamma + mM\cos\beta]\, d\pi_v \end{aligned}\right\} \qquad (55)$$

$$0 = \left\{\begin{aligned} &\omega_0 - \omega - \frac{1}{\sin\rho_0}[\sin\Delta_v \cos\sigma\, d(\alpha_s \sim \alpha_v) - \sin\sigma\, d\Delta_v + \cos\rho_0 \sin\omega_0\, d\Delta_s] \\ &- \frac{\cos\theta_s}{\sin\rho}[\pm (mM \pm N)\cos\gamma \tan\theta_s - N\sin\gamma + mM\sin\beta\cos\rho]\, d\pi_v \end{aligned}\right\} \qquad (56)$$

Each photograph furnishes one conditional equation of the form (55), and another of the form (56), and from all the equations thus obtained the values of $d(\alpha_s \sim \alpha_v)$, $d\Delta_s$, $d\Delta_v$, and $d\pi_v$ are found by the method of least squares, the resulting value of the solar parallax being

$$\pi_s + m\, d\pi_v \qquad (57)$$

At the time of the last transit the value of m was 0.2684. The term $\pm (mM \pm N)$ of equations (55) and (56) is to be interpreted thus: When the sun and Venus are on opposite sides of the meridian, it will be $+ (mM + N)$; when the sun and Venus are on the same side of the meridian, if the sun is most distant from the meridian, it will be $+ (mM - N)$; but if Venus is most distant from the meridian, then it will be $- (mM - N)$.

It will not escape notice that those parts of equations (55) and (56) which correspond to $\varrho_0 + d\varrho_0$, and $\omega_0 + d\omega_0$, of the equations (54), are general for the whole earth, and can therefore be tabulated at suitable intervals for the period of the transit; while the terms which correspond to $\varrho + d\varrho$, and $\omega + d\omega$, must be computed specially for each photograph.

WASHINGTON, Nov. 15, 1876

XVII.

ON DIAMIDO-SULPHOBENZIDE-DICARBONIC ACID.

By Arthur Michael and T. H. Norton.

Presented by E. N. Horsford, May 9th, 1877.

Of the large number of amido-sulpho-benzoic acids which are possible according to our present theories, but three have been obtained thus far. Two of these were prepared by Griess,* from the action of sulphuric acid on meta-amido-benzoic acid. Limpricht and Uslar † obtained the third by reduction of the mono-nitro derivative of meta-sulpho-benzoic acid. It seemed therefore of interest to us to study the action of sulphuric acid on ortho-amido-benzoic acid and para-amido-benzoic acids, not merely in order to increase the list of isomeric amido-sulpho-benzoic acids, but because of the possibility that, by removal of the amido group, the as yet unknown ortho-sulpho-benzoic acid could be obtained.

Our experiments were first directed to para-amido-benzoic acid; and here an unexpected character was assumed by the reaction, the results of which we briefly communicate.

We prepared the para-amido-benzoic acid for our purpose from the solid para-nitro-toluol, by oxidation and subsequent reduction of the nitro group. In the former operation it was observed that much better results were obtained from treatment with potassium permanganate, than from the methods hitherto used for this body, viz., with nitric acid or potassium bichromate and sulphuric acid. The best proportions were found to be 2½ mol. $KMnO_4$ to 1 mol. $C_6H_4(NO_2)(CH_3)$ in a solution of 40 parts water to 1 part $KMnO_4$. The reduction was effected by means of tin and hydrochloric acid, in proportions 1 part $C_6H_4(NO_2)(COOH)$ to 2.15 parts Sn. In order

* Jour. f. prakt. Chemie [2], 5, 244.
† Ann. Chem. Pharm., 106, 29.

to remove the excess of hydrochloric acid previous to the precipitation of the tin, the solution is evaporated on the water-bath to dryness. The temperature should not, however, go beyond this point, as we had opportunity to observe that even at 100° small quantities of aniline were formed, while at 120° the para-amido-benzoic acid was decomposed completely into carbonic acid and aniline. It would be of interest to examine the action of $SnCl_2$ on other aromatic acids under the conditions mentioned. The solution of para-amido-benzoic acid was treated with sodium carbonate, and the acid precipitated out by means of acetic acid. After a single crystallization in water, it showed the melting point 186°.

The para-amido-benzoic acid obtained in this way was placed in a flask, and a sufficient quantity of slightly fuming sulphuric acid (s. g. 1.850) added to dissolve the mass. The flask was then exposed to a temperature of 170° — 190°, for from three to four hours, in a paraffine bath. After cooling, the contents of the flask were removed by means of water, and barium-carbonate was added to the solution until it was neutralized. The liquid was boiled for several hours, and then filtered. It was necessary to heat the residue repeatedly with hot water before a slight pinkish hue could be removed. Exactly enough sulphuric acid was added to the filtrate to precipitate the barium, and it was separated from the barium sulphate formed. By the evaporation of this solution, groups of crystals separated out, showing various shades of yellow, orange, and red. Several crystallizations from water freed them from small quantities of a by-product consisting of minute red crystals, and after boiling with animal charcoal they retained a faint pink color. The substance was dried at 110°, and submitted to a series of analyses. The sulphonic acid which was expected as the natural result of the reaction, would have yielded the following percentages: —

$$C_6H_3\begin{cases} NH_2 \\ SO_3H \\ COOH \end{cases} = \begin{cases} C = 38.7 \\ H = 3.3 \\ S = 14.5 \\ N = 6.4 \end{cases}$$

The analyses showed, however, that we had obtained a body of an entirely different nature, and led to the following formula: —

$$C_{14}H_{12}N_2SO_6.$$

	Calculated.	Found (mean).
C =	50.00	50.18
H =	3.57	4.20
N =	8.26	8.06
S =	9.60	10.10
O =	28.57	
	100.00	

This formula would naturally be resolved into the structural formula,

$$SO_2\begin{array}{l}\diagup C_6H_3\begin{array}{l}\diagup NH_2\\ \diagdown COOH\end{array}\\ \diagdown C_6H_3\begin{array}{l}\diagup COOH\\ \diagdown NH_2\end{array}\end{array}$$

or diamido-sulphobenzide-dicarbonic acid, the reaction being as follows:—

$$2\,C_6H_4\begin{array}{l}\diagup NH_2\\ \diagdown COOH\end{array} + H_2SO_4 = 2\,H_2O + SO_2\begin{array}{l}\diagup C_6H_3\begin{array}{l}\diagup NH_2\\ \diagdown COOH\end{array}\\ \diagdown C_6H_3\begin{array}{l}\diagup COOH\\ \diagdown NH_2\end{array}\end{array}$$

The melting point of the acid is above 350°. It is easily soluble in hot water, and on cooling separates out in groups of fern-shaped crystals. It is much less soluble in alcohol and ether, their addition to the aqueous solution causing the precipitation of the acid in a white, flocculent mass; chloroform dissolves it with difficulty; while it is almost entirely insoluble in carbon bisulphide and benzine. Sulphuric acid dissolves it easily, forming a compound which is precipitated on the addition of alcohol, and is extremely soluble in water. This compound awaits farther investigation. In concentrated hydrochloric acid it is completely insoluble. It dissolves easily in warm nitric acid, but cannot be precipitated by the addition of alcohol.

The new compound exhibits strongly marked acid properties, and dissolves easily in alkalies. The neutral solution in ammonia yields on evaporation the ammonium salt, in handsome laminated crystals, which are easily soluble.

The potassium salt obtained in the same way consists of small, fine, colorless needles.

The lead salt is white, and nearly insoluble in water.

The silver salt precipitated from the solution of the ammonium salt by the addition of nitrate of silver, is obtained in the form of small, white laminæ, which are tolerably insoluble in water, and gradually assume a brown color on exposure to the sunlight. The analysis of this salt coincided closely with the formula

$$SO_2\begin{cases} C_6H_3\begin{cases} NH_2 \\ COOAg \end{cases} \\ C_6H_3\begin{cases} COOAg \\ NH_2 \end{cases} \end{cases}$$

Calculated.	Found.
$Ag = 37.45$	37.62

The barium salt is extremely soluble, and not adapted for analysis.

The reaction of para-amido-benzoic acid, just described, recalls the analogous reaction of phenol with sulphuric acid. Glutzt * and Annaheim † have shown that, if an excess of sulphuric acid be avoided, oxysulpho-benzide is obtained with great ease. As in the case of oxysulpho-benzide and all members of the sulphine group, our compound should also pass over into the corresponding sulphonic acid, by increasing the amount of sulphuric acid used.

Unfortunately we are compelled temporarily to interrupt the investigation, but hope at an early date to be able to communicate farther experiments in the direction mentioned.

Merz and Weith ‡ obtained several years since a dicarboxyl-sulphcarbanilid,

$$CS\begin{cases} NHC_6H_4COOH \\ NHC_6H_4COOH \end{cases}$$

a well-defined crystalline compound, by the action of carbon disulphide on metamido-benzoic acid. We have sought to prepare the corresponding derivative of para-amido-benzoic acid, but so far without success. The alcoholic solution of carbon disulphide and para-amido-benzoic acid was heated in an open flask and in sealed tubes at various temperatures. In all cases we obtained a yellow, resinous mass, from which no well-characterized compound could be separated.

BERLIN, UNIVERSITÄTS-LABORATORIUM, April, 1877.

* Ann. Chem. Pharm., 147, 52. † Ann. Chem. Pharm., 172, 28.
‡ Ber. Deutsch. Chem. Gesell., 8, 812.

XVIII.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

RESEARCHES ON THE SUBSTITUTED BENZYL COMPOUNDS.

By C. Loring Jackson.

Presented, June 14th, 1876.

INTRODUCTION.

The existence of the benzyl compounds was first established by Cannizaro,* in 1853; for, although Liebig and Wöhler,† in their classical research on the benzoyl compounds, obtained benzylalcohol as a secondary product from the action of potassic hydrate on benzaldehyd, they merely spoke of it as an oily liquid, and did not determine its composition or properties. It was also Cannizaro ‡ who, in 1855, showed that toluol, when treated with chlorine, yielded a substance identical with the benzylchloride prepared from benzylalcohol by means of hydrochloric acid. The nature of the action of chlorine on toluol was not, however, thoroughly understood until Beilstein and Geitner,§ in 1866, found that chlorine converted cold toluol into chlortoluol, while, with boiling toluol, it yielded benzylchloride. In the same paper, they predicted that pure chlorbenzylchloride could be prepared by the action of chlorine, either on hot chlortoluol or on cold benzylchloride. Both these methods were tried successfully by Neuhof ‖ in the same year, but the chlorbenzylchloride thus obtained was not the first substituted benzyl compound known, as Beilstein ¶ had already obtained the chlorbenzylmercaptan, and Naquet ** the chlorbenzylethylether, from the mixture of dichlortoluols, made by acting upon toluol

* Ann. Chem. Pharm., 88, p. 129.
† Ib., 3, p. 249.
‡ Ib., 96, p. 246.
§ Beilstein and Geitner, Ann. Chem. Pharm., 139, p. 331.
‖ Neuhof, Zeitschr. der Chem., '66, p. 653.
¶ Beilstein, Ann. Chem. Pharm., 116, p. 346.
** Naquet, ib., Sup. 2, p. 250. Comptes Rend., 56, p. 129.

with chlorine. Immediately after the preparation of the pure chlorbenzylchloride by Neuhof, many of its derivatives were studied by Beilstein and Kuhlberg and Neuhof;* and the two former extended their investigations to the chlorbenzyl compounds containing more than one atom of chlorine attached to the benzole ring. Since that time, but little attention has been given to this class of compounds; the only researches being those of Böhler,† and later, Vogt and Henninger,‡ on the sulphoacids, of Berlin,§ who obtained some curious results from the amines, and of Sintenis,‖ who investigated the ethers.

Beside these chlorbenzyl compounds, only two other classes of substances lying within the range of this paper have been studied, the nitrobenzyl compounds, — the first of which, nitrobenzylchloride, was described by Beilstein and Geitner in 1866, in the paper already referred to; ¶ its derivatives were further studied by Grimaux,** Beilstein, and Kuhlberg,†† Böhler,‡‡ Strakosch,§§ Czumpelik,‖‖ Radziszewski,¶¶ Henry,*** and Jackson; ††† and a few amidobenzyl compounds, the cyanide prepared by Czumpelik,‡‡‡ and the amines by Strakosch.§§§

All these substances belonged to the para series, and no isomeric chlor- or nitrobenzyl compounds were known with the exception, perhaps, of the monochlorbenzylsulphosalts described by Vogt and Henninger, ‖‖‖ and the isomeric nitrobenzylalcohol obtained by Gri-

* Beilstein, Kuhlberg, Neuhof, Ann. Chem. Pharm., 147, p. 339; ib., 150, p. 286; ib., 146, p. 319.

† Böhler, Zeitschr. Chem., 1868, p. 440.

‡ Vogt, Henninger, Ann. Chim. Phys. [4], 27, p. 130; Ann. Chem. Pharm., 165, p. 362.

§ Berlin, Ann. Chem. Pharm., 151, p. 137.

‖ Sintenis, ib., 161, p. 329.

¶ Beilstein and Geitner, Ann. Chem. Pharm., 139, p. 331.

** Grimaux, Comptes Rend., LXV., p. 211; Ann. Chem. Pharm., 145, p. 46.

†† Beilstein, Kuhlberg, Neuhof, Ann. Chem. Pharm., 147, p. 339; ib., 150, p. 286; ib., 146, p. 319.

‡‡ Böhler, Zeitschr. Chem., 1868, p. 440.

§§ Strakosch, Ber. D. Ch. G., 1872, p. 692.

‖‖ Czumpelik, ib., 1870, p. 473.

¶¶ Radziszewski, ib., 1870, p. 198.

*** Henry, ib., 1869, p. 637.

††† Jackson, ib., 1875, p. 321.

‡‡‡ Czumpelik, ib., 1870, p. 473.

§§§ Strakosch, ib., 1872, p. 692.

‖‖‖ Vogt, Henninger, Ann. Chim. Phys. [4], 27, p. 130; Ann. Chem. Pharm., 165, p. 362.

maux* from nitrobenzaldehyd, until Wachendorff,† in 1875, described the orthonitrobenzylbromide and chloride. Soon after, in a preliminary notice‡ of a portion of the work contained in these papers, the para- meta- and orthobrombenzylbromides were described; finally, in 1877, Wachendorff published a very interesting paper § upon the nitrobenzylchlorides and bromides, in which he described the metanitrobenzylbromide, and called attention to the striking fact that metanitrobenzylchloride could not be obtained under conditions which gave without difficulty the paranitrobenzylchloride, while he had not as yet succeeded in obtaining the orthonitrobenzylbromide under the conditions which furnished both of its isomeres; he said, however, that he did not despair of obtaining it by new experiments under different conditions; from this it would seem probable that the statements made in his preliminary notice in regard to orthonitrobenzylchloride and bromide, have been proved incorrect by his later experiments.

The object of these papers is to add to our knowledge of this little studied class of compounds, and, also, to make some comparisons between the replaceability of the haloid atoms in the side-chain, which it is hoped may in the future throw some light upon the nature of chemical attraction. The substituted benzylbromides have been used as the starting-point for each class of compounds, because these substances can be easily obtained by the action of weighed amounts of bromine upon the corresponding substituted toluols in the state of vapor. This action of bromine on boiling toluol was first studied by Lauth and Grimaux,‖ Cannizaro,¶ and Beilstein,** who proved that the substance thus formed was identical with the benzylbromide previously obtained by Kekule †† from benzylalcohol by means of hydrobromic acid.

FIRST PAPER.

ON CERTAIN SUBSTITUTED BENZYLBROMIDES.

C. Loring Jackson.

Parabrombenzylbromide ($C_6H_4\overset{p}{Br}.CH_2Br.$). — Preparation. First Method. Ten grammes of pure parabromtoluol, melting-point 28.5°,

* Grimaux, Comptes Rend., LXV., p. 211; Ann. Chem. Pharm., 145, p. 46.
† Wachendorff, Ber. D. Ch. G., 1875, p. 1101.
‡ Jackson, ib., 1876, p. 931.
§ Wachendorff, Ann. Chem. Pharm., 185, p. 259.
‖ Lauth and Grimaux, Bull. Soc. Chim. [2], VII., p. 108.
¶ Cannizaro, Ann. Chem. Pharm., 141, p. 198.
** Beilstein, ib., 143, p. 369.
†† Kekule, Ann. Chem. Pharm., 137, p. 188.

obtained from the factory of Kahlbaum in Berlin, or of Schuchardt in Görlitz, were heated to boiling in a small flask through whose cork passed a return-cooler and the delivery-tube from a flask containing 10 gr. of bromine, the end of which within the flask was less than a centimeter above the surface of the bromtoluol; the bromine was driven over in the form of vapor by heating the flask containing it with a small flame placed some distance below at such a rate that it was completely decolorized at a few centimeters from the end of the exit-tube; to prevent condensation of the bromine, the delivery-tube was made as short as possible; the heat was carefully regulated so that the bromtoluol boiled gently, the explosive boiling with evolution of white fumes, which was apt to occur toward the end of the process, being especially avoided. If these precautions were observed, the liquid solidified almost completely on cooling, and the substance was easily purified by pressing the crystals thus obtained between filter-paper and recrystallizing once or twice from hot alcohol. The average yield from ten grammes of parabromtoluol was ten grammes of parabrombenzylbromide, that is about sixty-eight per cent of the theoretical amount; but, if more than ten grammes of parabromtoluol were used in one operation, the yield was not so large.

The substance was also obtained from the mixture of para- and orthobromtoluol,* prepared by treating cold toluol with bromine. On cooling the product of the action of bromine on the hot mixture with ice and salt, some parabrombenzylbromide separated out, and more was obtained by distilling off a part of the oil with steam, as the orthobrombenzylbromide distils more easily with steam than the paracompound. This distillation is not to be recommended, however, as under these conditions a portion of the bromide is converted into the corresponding alcohol; but without doubt this difficulty could be removed by using hydrobromic acid in place of water. Compare p. 214.

Second Method. Benzylbromide was treated in the cold, with an equal weight of bromine, to which a little iodine had been added; on freezing the product of the reaction, a quantity of parabrombenzylbromide separated out. This method is decidedly inferior to that with pure parabromtoluol, as it not only gives a smaller yield, but also there is a possibility that orthobrombenzylbromide may be formed. The composition of the parabrombenzylbromide was established by the following analyses: —

0.5934 gr. of substance gave 0.7377 gr. CO_2 and 0.1378 gr. H_2O.

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* Ann. Chem. Pharm., 147, p. 39.

0.5679 gr. of substance gave, after ignition, with CaO 0.8579 gr. AgBr.

	Required for $C_7H_6Br_2$.	Found.
Carbon	33.6	33.90
Hydrogen	2.4	2.57
Bromine	64.0	64.28
	100.0	100.75

Properties.— Crystallized from alcohol, it forms thick, colorless needles, with a brilliant lustre; from the oily mother-liquor formed in its preparation or from benzole, it separates on slow evaporation in well-formed prisms, apparently of the orthorhombic system, often a centimeter or more long and two to four millimeters thick, which have the consistency of sublimed sal-ammoniac. Its odor is agreeable and aromatic, but its vapor attacks the mucous membrane with very great violence, causing tears and running at the nose; it was observed, however, by all who were exposed continually to its action that they became much less sensitive to it after a few days. When brought upon the more delicate parts of the skin, it causes a sharp, stinging pain, but produces no such effect on the hands; the taste is extremely biting, causing great pain to the tongue for several minutes; it melts at 61½°, can be distilled with steam, sublimes in needles, and burns with a luminous green-bordered flame. It is almost insoluble in water, although it imparts its odor to it; (the flat needles, mentioned in a preliminary paper* as separating from water by spontaneous evaporation, were undoubtedly the more soluble parabrombenzylalcohol); it is but slightly soluble in cold, freely in hot alcohol, very readily in ether, benzole, carbonic disulphide, and glacial acetic acid. On one occasion, it was oxidized very rapidly by a mixture of potassic dichromate and dilute sulphuric acid, the action being attended by flashes of light visible even in diffused daylight, the product was an acid melting in the crude state at 239° to 240°, which must therefore be parabrombenzoic acid.

It seems highly probable that this parabrombenzylbromide is the substance obtained, but not purified or studied by Lauth and Grimaux,† in 1866, in the residue from the distillation of bromtoluol; since they described it as crystallizing in needles, and in the highest degree irritating to the eyes.

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* Ber. D. Ch. G., 1876, p. 931.

† Lauth and Grimaux, Bull. Soc. Chim. [2], V. p. 347.

Metabrombenzylbromide ($C_6H_4\overset{3}{Br}.CH_2Br$) was made from metabromtoluol, prepared by Wroblevsky's* method (compare also Grete†), as follows: 30 gr. of the mixture of para- and orthoacettoluid, obtained as a secondary product in Wroblevsky's process for purifying orthotoluidin, previously reduced to a granular condition by crystallization from boiling-water, were suspended in cold water, and 45 gr. of bromine dissolved in water added in small portions at a time, shaking until the yellow color disappeared after each addition; the acetyl group was removed from the metabromacettoluid thus obtained by boiling with fuming hydrochloric acid in a flask with a return-cooler; the base, set free by an alkali, was dissolved in portions of 10 gr. at a time in absolute alcohol, and the amido group replaced by hydrogen by Griess's reaction; the alcohol was then partly distilled off on the water-bath; the residue distilled with steam, dried, and rectified, the portion passing over from 179° to 185°, being collected. To convert this into metabrombenzylbromide, 10 gr. of it were heated to boiling, and treated with 12 gr. of bromine in the way described under parabrombenzylbromide (see page 212); the slight excess of bromine over the molecular proportion was taken to allow for the loss in the process; the metabromtoluol took up the bromine somewhat more slowly than the parabromtoluol. The liquid left after the bromiring was finished, was distilled in a current of the vapor from hydrobromic acid (boiling-point 125°), prepared according to Naumann,‡ until a considerable portion had passed over: the flask containing the substance was not heated for fear of decomposition. The hydrobromic acid vapor cannot be replaced by steam; as under these conditions some of the brombenzylalcohol might be formed, although I am inclined to think that this reaction would take place much less readily here than it does in the case of the parabrombenzylbromide (compare page 212). The residue left in the flask was transferred to a funnel-tube, closed with a rubber stopper on a glass rod, and surrounded with ice. If the distillation had been carried on long enough, nearly the whole of the oil solidified to a dark, pasty mass. The stopper was then removed, and the brown oil sucked out as completely as possible by means of the Bunsen pump. The white scales left on the funnel were boiled with a small quantity of alcohol; the clear solution poured off from the undissolved oil and cooled in a corked flask. As soon as no more oil was

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* Wroblevsky, Ann. Chem. Pharm., 168, p. 153.

† Grete, ib., 177, p. 231.

‡ Naumann, Ber. D. Ch. G., 1876, p. 1574.

deposited, the clear liquid was decanted into another flask, and cooled with ice, when crystals were formed. The same process was repeated with the mother-liquor and the residue until the whole was converted into crystals; while another crop of less pure metabrombenzylbromide was obtained by adding snow to the mother-liquor from the final operation. The crystals were purified by similar crystallizations from hot alcohol. It was necessary that all these operations should be carried on in corked flasks, as the metabrombenzylbromide, when moistened with alcohol, evaporated when exposed to the air so rapidly that there was a very considerable loss from working with open vessels.

The composition of the metabrombenzylbromide was established by the following analyses: —

0.4333 gr. substance gave after ignition with CaO 0.6609 gr. AgBr.

	Required for $C_7H_6Br_2$.	Found.
Carbon	33.6	34.63
Hydrogen	2.4	2.66
Bromine	64.0	63.96
	100.0	101.25

Properties.—Crystallized from alcohol by cooling, it forms white bladed needles or plates arranged in radiated groups; by slow evaporation of its alcoholic solution, it can be obtained in flat prisms with square ends sometimes reaching a length of 3 cm., and a breadth of 2 mm. It has an agreeable odor, aromatic, but different from that of the parabrombenzylbromide, while its action on the mucous membrane is even more violent, perhaps because it is more volatile; its taste and action on the more delicate parts of the skin is similar to that of the para compound; it melts at 41°, can be distilled with steam only very slowly, sublimes in oily drops, and burns with a luminous flame having a green border. One of its most striking properties is that, when moistened with alcohol or ether, it evaporates very rapidly; whereas when dry it is comparatively fixed. It is almost insoluble in water, but imparts its odor to it, is freely soluble in cold, still more so in hot alcohol, and very readily soluble in ether, benzole, carbonic disulphide, and glacial acetic acid. An oxidizing mixture of potassic dichromate and dilute sulphuric acid seems to be without action on it; but the same mixture converts the alcohol derived from it into an acid, which, in a not perfectly pure state, melts at 151°, and must therefore be metabrombenzoic acid.

Orthobrombenzylbromide ($C_6H_4\overset{o}{Br}.CH_2Br.$). — After several unsuccessful attempts to obtain an orthobromtoluol free from the para com-

pound from the mixture prepared by adding bromine to cooled toluol, I decided to insure a perfectly pure substance as my starting-point, by making the orthobromtoluol from orthotoluidin. The first method employed for purifying the orthotoluidin was that of Wroblevsky,* by boiling crude toluidin sixteen hours with glacial acetic acid; but all the samples obtained by this process contained traces of paratoluidin. After I had convinced myself by experiment that the methods of Rosenstiehl,† by treating the oxalates with ether; and of Beilstein and Kuhlberg,‡ by precipitating an acetic acid solution of acettoluid with water, — were almost impracticable for large quantities, I tried the method of Schad,§ recommended by Kekule,‖ which depends on the crystallization of the nitrates and chlorides, and in this way succeeded in obtaining a liquid toluidin which with acetylchloride gave an acettoluid melting after one recrystallization from boiling-water at 107°. As some previous attempts to convert orthotoluidin into orthobromtoluol by the usual method through the diazoperbromide had given me as unsatisfactory a yield as that obtained by Wroblevsky,¶ I treated this according to a new modification of the process of Hübner and Majert ** for preparing parachlortoluol, which I had found to work admirably in making that substance. This modification was suggested by Victor Meyer's †† method of applying Griess's reaction, and consisted in dissolving 20 gr. of the orthotoluidin in an excess of hydrobromic acid (boiling-point 125°, prepared according to Naumann ‡‡); the pasty mass was then treated with somewhat more than the calculated amount of solid potassic nitrite, which was thrown in in small portions at a time, the flask being corked after each addition, and shaken until all the red fumes were absorbed; after the last portion of nitrite had been added, the greater part of the liquid was distilled off, and the residue then treated again in the same way. The distillate consisted of dilute hydrobromic acid and a heavy oily liquid which was separated with a drop-funnel, washed with potassic hydrate solution until the odor of kresole was removed, then with water, and finally dried and rectified; in this way 40 grammes of orthotoluidin gave 29 grammes of crude

* Wroblevsky, Ann. Chem. Pharm., 168, p. 162.
† Rosenstiehl, Zeitschr. Chem., 1868, p. 557, 666.
‡ Beilstein, Ann. Chem. Pharm., 156, p. 75.
§ Schad, Ber. D. Ch. G., 1873, p. 1361.
‖ Kekule, Ber. D. Ch. G., 1874, p. 1006.
¶ Wroblevsky, Ann. Chem. Pharm., 168, p. 171.
** Hübner and Majert, Ber. D. Ch. G., 1873, p. 794.
†† V. Meyer, Ber. D. Ch. G., 1875, p. 1074, note.
‡‡ Naumann, Ber. D. Ch. G., 1876, p. 1574.

orthobromtoluol, and 24 grammes of this gave on the first fractioning 19 grammes of a colorless liquid boiling between 179° and 182°; that is, about thirty-six per cent of the theoretical yield, whereas the diazoperbromide furnishes under the best conditions only ten per cent. The new method has the further advantages of taking much less than half the time occupied by either of the old ones, and the product is not contaminated with the nitro compounds which compelled Hübner and Majert to reduce before rectifying. Von Richter * has also obtained tetrabrombenzole by the action of nitrous anhydride on a mixture of tribromaniline with hydrobromic and glacial acetic acids; he ascribes the reaction to the presence of the negative atoms, and announces his intention of trying similar experiments with compounds containing fewer bromine atoms or nitro groups; that the reaction is not due to the presence of such negative radicals is proved by the previous researches of Hübner and Majert, which he seems to have overlooked, and the results given above. I should not have intruded on Von Richter's field of work, had it not been necessary for me to obtain the orthobromtoluol, but I felt the less hesitation in doing so, as I am unable to see that his method differs in any essential particular from that of Hübner and Majert, published nearly two years before the appearance of his article.

The orthobromtoluol was converted into orthobrombenzylbromide by treatment with bromine in the way described under the para compound. The purification of the substance was a matter of some difficulty, as it seemed to be completely decomposed by rectification, and converted into the alcohol by distillation with steam; the method finally adopted was distillation in a stream of the vapor from aqueous hydrobromic acid, as described under the metabrombenzylbromide; the first fifth of the distillate was rejected to make sure of the absence of orthobromtoluol; that which came over later was washed till it ceased to give an acid reaction, and then dried *in vacuo*. In this way, 17 grains of pure orthobrombenzylbromide were obtained from 18 grains of orthobromtoluol.

Its purity was established by the following bromine determination: —

0.5035 gr. of substance gave after ignition with CaO 0.7608 gr. of AgBr.

	Required for $C_7H_6Br_2$.	Found.
Bromine	64.0	64.30

* Von Richter, Ber. D. Ch. G., 1875, p. 1428.

A number of bromine determinations made in products from distillation with steam gave invariably results which were below the theory.

Properties. — It forms a pale yellow oil (the color is undoubtedly due to a trace of some impurity), with an agreeable odor, somewhat resembling that of parabrombenzylbromide, and an action on the mucous membrane even more violent than that of the preceding compounds; its boiling-point seems to lie between 250° and 260°, but could not be determined with accuracy because it is decomposed with evolution of hydrobromic acid by boiling. A careful study of the action of heat on this and the allied substances is reserved for a future paper. It does not solidify even at — 15°, can be distilled with steam, burns with the usual luminous green-bordered flame, and does not mix with water, although it imparts its odor to it, but mixes readily with absolute alcohol, ether, benzole, glacial acetic acid, and carbonic disulphide. It does not seem to be attacked by a mixture of potassic dichromate and dilute sulphuric acid, but the alcohol derived from it is completely destroyed by this oxidizing mixture.

Parachlorbenzylbromide, $C_6H_4ClCH_2Br$, was prepared from parachlortoluol; melting-point, 6°.5; boiling-point, 158°–161°; made by the modification of the method of Hübner and Majert, already described in connection with orthobromtoluol (see page 216); crude fuming hydrochloric acid took the place of the hydrobromic acid, and 40 gr. of paratoluidin were used for each operation; the oil, after washing with potassic hydrate, proved on rectification to be almost absolutely pure parachlortoluol, the yield being about 13 gr. It was converted into parachlorbenzylbromide in the way already described; the product of the reaction deposited crystals on cooling, which were drained, and a fresh crop obtained from the mother-liquor by heating it gently for a few minutes in a watch-glass placed on a sand-bath, and then allowing it to stand for some time. The crystals after pressing between filter-paper were purified by crystallization from hot alcohol in corked flasks, as the substance is so volatile that work in open vessels would have been attended with great loss; upon cooling the solution with ice, a little oil separated; and if the liquid was then stirred it immediately became filled with beautiful white needles. On one occasion, the substance was distilled with steam in order to obtain it perfectly white, but this is not to be recommended, as the water left in the distillation-flask deposited long thin ribbons melting at 66°, and therefore evidently the parachlorbenzylalcohol, while the supernatant liquid contained hydrobromic acid. This

observation furnished a very neat and convenient way of obtaining the corresponding alcohols from the bromides. (See parabrombenzylalcohol in the next paper, p. 221).

The composition of the parachlorbenzylbromide was established by the following analyses: —

0.3399 gr. of the substance gave after ignition with CaO 0.5580 gr. AgBr+AgCl.

0.4224 gr. of substance gave 0.6779 gr. AgBr+AgCl.

	Required for $C_7H_6Cl\,Br$.	Found.	
Chlorine and Bromine	56·20	57·20	55·94

Properties. — By slow evaporation of its alcoholic solution, it can be obtained in well-formed colorless prisms, by cooling in radiated bunches of needles often three centimeters long; it has an agreeable aromatic odor, and acts on the mucous membrane more violently than any of the other substances described in this paper; it melts at 48½°, sublimes in oily drops, can be distilled with steam, is very volatile at ordinary temperatures, so that a crystal will evaporate completely if exposed to the air for a few days, and burns with a flame similar to that of the bromine compounds. It is slightly soluble in water, easily soluble in cold, still more so in hot alcohol, and very readily in ether, benzole, carbonic disulphide, and glacial acetic acid. It is attacked with difficulty, if at all, by potassic dichromate and dilute sulphuric acid.

Paraiodbenzylbromide, $C_6H_4ICH_2Br$, was made from paraiodtoluol; melting-point, 35°; prepared according to Körner * by the action of hydriodic acid on the nitrate of diazotoluol, this last being obtained by Victor Meyer's † excellent modification of Griess's reaction. The introduction of the bromine into the side-chain by treating the boiling substance with bromine vapor was much more difficult than in the preceding cases; the precautions to be observed were in general the same as those given under parabrombenzylbromide; but occasionally, in spite of all possible care, a black tarry liquid was the only result of the process. The conditions under which the paraiodbenzylbromide is formed are now undergoing very careful study by Mr. C. F. Mabery, and the results will be published in his paper upon the paraiodbenzyl compounds. It is a very remarkable fact that in several cases, when the paraiodtoluol was not perfectly pure, the liberation of iodine in considerable quantity was observed during the bromiring; but, in spite of this, the product contained paraiodbenzylbromide, thus apparently

* Körner, Bull. Acad. Roy. Belg. [2], 24, p. 157.

† V. Meyer, Ber. D. Ch. G., 1875, p. 1074, note.

furnishing an exception to the general rule of Beilstein that, in presence of iodine, bromine goes into the benzole ring even at high temperatures. The product of the reaction, if properly managed, solidified on cooling, and was best purified by standing on paper, which sucked out a quantity of black oil, and afterward by repeated crystallizations from boiling alcohol with the assistance of bone-black.

The composition of the paraiodbenzylbromide was determined by the following analyses: —

0.3721 gr. of substance yielded 0.3773 gr. CO_2 and 0.0773 gr. of H_2O.
0.1774 gr. of substance gave, according to Carius, 0.1285 gr. of Ag.
0.1971 gr. of substance gave 0.2755 gr. of AgBr+AgI. There were indications in this analysis that the oxidation had not been complete.

	Required for C_7H_6IBr.	Found.	
Carbon	28·28	27·66	
Hydrogen	2·03	2·31	
Iodine and Bromine	69·69	69·47	68·41
	100·00	99·44	

Properties.—Crystallized from alcohol, it forms flattened needles, which usually have a straw yellow color, but can be obtained white by repeated recrystallization with boneblack. It has an aromatic odor and attacks the mucous membrane much less violently than any of the other substances mentioned in this paper; this, however, is very probably due to the fact that it is not readily volatile at ordinary temperatures; it melts at 78¾°; does not distil with steam or only with great difficulty; sublimes in needles; burns with a luminous green-bordered flame; and is insoluble in water, almost so in cold, much more soluble in hot, alcohol, but slightly soluble in glacial acetic acid, freely in ether, benzole, and carbonic disulphide. It is not easily attacked if at all by an oxidizing mixture of potassic dichromate and dilute sulphuric acid.

That all the substances mentioned in this paper contain bromine in the side-chain is proved by the fact that, when boiled with alcoholic sodic acetate, each one of them yields the corresponding substituted benzylacetate, from which the alcohol can be obtained by heating with aqueous ammonia at 150° to 160°. The description of these compounds, as well as of certain other derivatives of these substances, will be found in the following articles of this series. For descriptions of the parachlorbenzyl compounds the reader is referred to the papers already cited in the introduction.

SECOND PAPER.

ON PARABROMBENZYL COMPOUNDS.

WOODBURY LOWERY.

Parabrombenzylalcohol ($C_6H_4Br\,CH_2\,OH.$) — This substance was most easily prepared by boiling parabrombenzylbromide with water, in a flask with a return-cooler, for two or three days, until it no longer attacked the eyes. The reaction ran as follows: $C_6H_4BrCH_2Br + H_2O = C_6H_4BrCH_2OH + HBr$. The presence of the hydrobromic acid was established by treating the acid aqueous filtrate with argentic oxide, when argentic bromide was formed, and the solution became neutral. This method is analogous to that employed by Grimaux * for converting tollylenebromide into tollyleneglycole, except that Grimaux heated the haloid compound with water at 170° to 180°, while I obtained the alcohol by boiling in a flask with a reverse-cooler. The action of water on benzylchloride at high temperatures has been very thoroughly studied: the first research in this field having been undertaken by Limpricht † as early as 1866, who by heating the two substances to 190° obtained anthracene, a hydrocarbon $C_{14}H_{14}$, later identified by Van Dorp ‡ as benzyltoluol, and benzylether, which he supposed was formed from benzylalcohol; but neither he, nor Van Dorp, nor Zincke, § who afterward made out the theory of this reaction, mentioned obtaining benzylalcohol in this way. The alcohol was also obtained in the ordinary way by heating parabrombenzylacetate with aqueous ammonia in a sealed tube to 160°. The alcohol in whichever way prepared was purified by crystallization from boiling water, and its composition established by the following combustion: —

	Required for $C_7H_6Br.OH$.	Found.
Carbon	44.92	44.94
Hydrogen	3.74	3.99

Properties. — It forms long elastic transparent colorless flattened needles, with a brilliant pearly lustre and a disagreeable odor; its vapor does not attack the eyes. Melting-point, 69°. It burns with a luminous green-bordered flame, distils with steam although slowly, and is very slightly soluble in cold, more freely in boiling water, easily soluble in alcohol, ether, benzole, and carbonic disulphide.

* Grimaux, Comptes Rend., 70, p. 1363; Ann. Chem. Pharm., 155, p. 338.
† Limpricht, Ann. Chem. Pharm., 139, 303.
‡ Van Dorp, ib., 169, 207.
§ Zincke, Ber. D. Ch. G., 1874, 276.

The *parabrombenzylacetate* ($C_6H_4Br.CH_2C_2H_3O_2$) was not obtained in a condition pure enough for analysis. On adding water to the alcoholic solution left after boiling parabrombenzylbromide with sodic acetate and absolute alcohol, a more or less dark-colored oil which did not attack the eyes or nose was precipitated: this was dried and fractioned. In the first rectification the greater part came over at about 253°, but on fractioning again a considerable portion came over at lower temperatures; the oftener it was distilled, the less constant became the boiling-point, and after several distillations crystals appeared both in the residue and distillate, while nearly one quarter of the entire amount came over below 100°, and another quarter below 247°; all these fractions attacked the eyes with great energy, whereas the acetate before fractioning did not possess this property; the crystals were little white needles which dissolved readily in ammonic hydrate, and gave a silver salt which was analyzed. 0.2822 gr. of the salt gave 0.1009 gr. of Ag.

	Required for $C_6H_4Br.COOAg$.	Found.
Silver	35.06	35.75

As the acid melted at 240° to 250°, there could be no doubt that it was parabrombenzoic acid. Unfortunately the amount of parabrombenzylacetate at my disposal was so small that it was impossible to isolate the other products of this interesting decomposition, and the complete study of this reaction must therefore be postponed until next year, when it will be undertaken in this laboratory.

The acetate before fractioning was an oily liquid heavier than water, having an agreeable odor distantly resembling that of acetic ether, and burning with a luminous green-bordered flame; the boiling-point could not be determined with accuracy on account of the decomposition described above, but probably lies between 250° and 260°.

Parabrombenzylcyanide ($C_6H_4Br.CH_2CN$), was obtained by boiling parabrombenzylbromide with an alcoholic solution of potassic cyanide as long as potassic bromide was formed; on addition of water a yellow oil was precipitated, which deposited crystals after standing for some time, and finally solidified completely. The crystals were drained on filter-paper, and purified by crystallization from alcohol. Their composition was determined by the following volumetric nitrogen determination: —

0.3565 gr. substance gave 20 cc. nitrogen under a pressure of 742 mm., and a temperature of 9°.

	Required for $C_7H_6Br.CN$.	Found.
Nitrogen	7.10	6.58

Properties. — The substance separates from the oil at first obtained, either in flat truncated octahedra with a marked basal cleavage belonging either to the tetragonal or orthorhombic system, and having a very strong resemblance to the crystals of ferrocyanide of potassium, or else in flat twins imitating in a very beautiful manner the architectural forms of the trefoil and quatrefoil. These crystals are yellowish white, but the substance is rendered colorless by crystallization from alcohol; it has a disagreeable odor, does not attack the eyes, melts at 46°, burns with a luminous green-bordered flame, and is insoluble in water, moderately soluble in cold, freely in hot alcohol, soluble in ether and glacial acetic acid, still more readily in carbonic disulphide and benzole; by boiling with alcoholic potassic hydrate or heating in a sealed tube with hydrochloric acid it is easily converted into parabromalphatoluylic acid. It is to be remarked that the chlorbenzylchloride, according to the observations of Neuhof,* gave when heated as above with alcoholic potassic cyanide, the amide of chloralphatoluylic acid, the cyanide being obtained only by heating the substances in a sealed tube; this difference in the behavior under like conditions of two substances so nearly related as chlorbenzylchloride and parabrombenzylbromide is interesting.

Parabromalphatoluylic Acid ($C_6H_4Br.CH_2COOH$). This substance was most easily obtained by heating the cyanide with crude fuming hydrochloric acid to 100° in a sealed tube. On cooling, the liquid was found to be full of shining flattened needles of the acid, another portion of which had fused on the side of the tube; this method gave better results more neatly than the saponification with potassic hydrate; the acid was purified by recrystallization from boiling water, and its composition established by analyses of its silver and copper salts. (See below.)

Properties. — It crystallizes in white glistening flattened needles with but little odor, melts at 114.5°, sublimes above its melting-point in little plates, and burns with the usual luminous green-bordered flame. It is but slightly soluble in cold, freely in boiling water, and in alcohol, ether, benzole, carbonic disulphide, and glacial acetic acid. Ammonic and sodic hydrates dissolve it at once, forming the corresponding salts; it seems to decompose carbonates, but very slowly and imperfectly: potassic dichromate and dilute sulphuric acid convert it with some difficulty into parabrombenzoic acid melting in an impure state near 240°.

* Zeitschr. Chem. 1866, p. 653.

In 1869, Br. Radziszewski * obtained a substance which he called parabromalphatoluylic acid, by the action of bromine in the cold upon alphatoluylic acid; he does not describe it fully, but only says that it crystallizes in prisms melting at 76°, and gives baric and calcic salts crystallizing in warts, and easily soluble in water and alcohol, by oxidizing it with potassic dichromate and dilute sulphuric acid he obtained nothing but parabrombenzoic acid melting at 251°. He also obtained in the same operation another acid containing bromine, which melted at 99°, and was not further examined. The discrepancy between my results and those of Radziszewski, is probably due to the fact that he did not obtain a pure parabromalphatoluylic acid, but that the two acids observed by him were mixtures of para and ortho compounds, with perhaps some of the phenylbromacetic acid, C_6H_5CHBrC OOH, melting-point 82°, discovered by him in conjunction with Glaser,† and which he shows in the paper under discussion, is formed from the alphatoluylic acid by the action of bromine at 150°. The presence of a small quantity of orthobromalphatoluylic acid could easily lower the melting-point from 114.°5 to 99°, or even 76°; and, as it would be entirely consumed by oxidizing with potassic dichromate and sulphuric acid, such a mixture would yield only parabrombenzoic acid. On the other hand, my acid being prepared from pure parabrombenzyl-bromide, by processes in which the temperature never rose above 100°, must be perfectly free from isomeres; and this view is confirmed by the fact that its melting-point is higher than that of the acid obtained by Radziszewski.

Ammonic parabromalphatoluate obtained by dissolving the acid in ammonic hydrate, and driving off the excess of ammonia on the water-bath, crystallized in long curving groups of colorless needles very soluble in water.

Argentic parabromalphatoluate ($C_6H_4Br.CH_2COOAg.$) was precipitated by adding the ammonic salt to argentic nitrate, as a white curdy mass similar in appearance to chloride of silver; it was washed with cold water, and dried at 60°.

0.3106 gr. of the salt dissolved in dilute nitric acid, and precipitated with hydrochloric acid, gave 0.1375 gr. AgCl.

	Required for $C_7Br.H_6CO_2$ Ag.	Found.
Silver	33.57	33.33

* Radziszewski, Ber. D. Ch. G., 1869, p. 207.
† Zeitschr. Chem., 1868, p. 140.

It is almost insoluble in water, perhaps a little more soluble in hot than in cold, but it could not be obtained crystallized; it is readily soluble in dilute nitric acid; it blackens slightly by exposure to the light, and even at a temperature of 60°.

Cupric parabromalphatoluate, $Cu\ (C_6H_4Br\ CH_2COO)_2$, was precipitated as a flocculent bluish green solid, on mixing cupric sulphate with the ammonic salt.

0.3028 gr. of the salt gave 0.05028 CuO.

	Required for $Cu(C_8H_6Br.O_2)_2$.	Found.
Copper	12.90	13.24

It is insoluble in water, but soluble in dilute hydrochloric acid.

The *baric salt*, obtained by neutralizing a solution of the acid with baryta water and evaporating, formed white indistinctly crystalline crusts easily soluble in water.

The *calcic salt* obtained in a similar way, and also, although very slowly from calcic carbonate and a solution of the acid, appeared in the form of white warts; which, under the microscope, were seen to be globular groups of sharp needles looking somewhat like a chestnut-bur; it was easily soluble in water.

The behavior of a solution of ammonic parabromalphatoluate with solutions of the following salts was also observed:—

Mercurous salts, a heavy flocculent white precipitate.

Mercuric salts, a slight white precipitate.

Plumbic salts, a heavy white precipitate, somewhat soluble in boiling water, and separating from this solution in crystalline flocks.

Ferric salts, a pale yellow amorphous precipitate, while Chromic, Aluminic, Manganous, Cobaltous, Nickelous, Zincic, and Magnesic salts produced no precipitate.

Triparabrombenzylamine, $(C_6H_4Br.CH_2)_3\ N$, was formed even in the cold, when alcoholic ammonia was added to the parabrombenzylbromide; the white crystals which separated in large quantity were washed with water, and then recrystallized repeatedly from alcohol; in this way the triparabrombenzylamine was easily separated from its bromhydrate, which is very slightly soluble even in hot alcohol, and two sorts of crystals of the former substance were obtained, one in irregular somewhat bent thick needles, the other in fan-shaped groups of fine needles, both had the same melting-point, seemed to be about equally soluble in alcohol, and mutually convertible under conditions which could not be determined; it was therefore assumed that they were identical, and this assumption seems to be confirmed by the following analyses: —

I. 0.5397 gr. of the thicker needles gave 12 cc. nitrogen, at 757.4 mm., and 20° t.

II. 0.2664 gr. of the fan-shaped crystals gave 5.2 cc. nitrogen, at 763.1 mm. and 17.°5. t.

	Required for $(C_7H_6Br.)_3N$.	Found. I.	Found. II.
Nitrogen	2.67	2.53	2.26

Owing to the small amount of the fan-shaped crystals which could be isolated, I have not been able to establish its composition more securely by a second analysis.

Properties. — It crystallizes either in thick irregular white prisms or fan-shaped groups of white needles, is odorless, melts at 78°–79°, burns with the green-bordered luminous flame belonging to all these compounds, and is insoluble in water, soluble in cold, more so in hot alcohol, freely soluble in ether, benzole, and carbonic disulphide. All attempts to obtain a salt with hydrochloric acid alone, or in connection with platinic chloride were unsuccessful.

Triparabrombenzylamine bromhydrate, $(C_6H_4Br.CH_2)_3NH\,Br$, was formed at the same time as the free base, and separated from it by boiling out the product of the reaction, with alcohol; the viscous residue left after the removal of the triparabrombenzylamine by this means was dissolved in ether, from which it crystallized on evaporation.

0.4269 gr. of the substance gave 8 cc. nitrogen, at 767.7 mm. and 17° t.

0.4713 gr. of substance gave 0.5818 gr. AgBr.

	Required for $(C_7H_6Br.)_3NH\,Br$.	Found.
Nitrogen	2.29	2.19
Bromine	52.54	52.54

Properties. — White odorless plates with a pearly lustre, melting in the neighborhood of 270°, is insoluble in hot or cold water, almost insoluble in alcohol even when boiling, soluble although not very easily in ether, gives no double salt with platinic chloride.

The formation of triparabrombenzylamine as the principal product of the reaction is not to be wondered at, as benzylbromide gives a similar result when treated with alcoholic ammonia (Kekule*). It is not impossible, however, that some di- or even mono-parabrombenzylamine bromhydrate was formed, as this would undoubtedly have been

* Kekule Ann. Chem. Pharm., 137, p. 188.

the product of the reaction with water, and this unfortunately lost before it was investigated.

sulphocyanate ($C_6H_4Br.CH_2SCN$) was obtained by with alcoholic potassic sulphocyanate, and purifying from alcohol at low temperatures. I have but one sulphur determination of this substance, but have not thought importance to go through the purification of a fresh which is rendered difficult by its low melting-point, in order this result.

gr. of substance gave .2339 gr. of $Ba.SO_4$.

	Required for $C_7H_6Br.SCN$.	Found.
Sulphur	14.03	13.08

— It forms white ribbons often 5 cm. long, made up of united together laterally, having a strong odor similar to that ylsulphocyanate, melting at 25°, and soluble in alcohol. The ingly low melting-point rendered the management of the substance very difficult, and preserving the crystals impossible; it also — as nzylsulphocyanate melts at 36°–38°, according to Henry;* at according to Barbaglia † — throws doubt on the analysis given , and therefore on the correctness of the formula.

The investigation of the parabrombenzyl compounds will be continued this laboratory; the next portion of the subject to be studied being action of heat, superheated steam, and sodium on these bodies.

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* Henry, Ber. D. Ch. G., 1869, p. 637.

‡ Barbaglia, Ber. D. Ch. G., 1872, p. 687.

XIX.

CONTRIBUTION TOWARDS THE HISTORY OF THE FLUORIDES OF MANGANESE.

By W. H. Melville.

Presented by the Corresponding Secretary, June 14th, 1876.

The investigation described in this paper was undertaken with a view to the re-examination of the fluorides of manganese. Many investigations have been made upon this subject during this century, and necessarily a large amount of fact has been accumulated.

* Berzelius noticed that, on the evaporation of a solution of manganous carbonate in hydrofluoric acid, ill-defined crystals were obtained, which dissolved in water only when containing an excess of acid. This amethyst-colored substance he called the proto-fluoride of manganese. He furthermore prepared a fluoride of manganese and potassium by double decomposition of a solution of manganous sulphate and fluoride of potassium. Similarly the soda salt was precipitated. These double fluorides were described as white precipitates, insoluble in water, and soluble in acids.

† When hydrated sesquioxide of manganese is dissolved in hydrofluoric acid and the solution left to evaporate spontaneously, dark brown prisms crystallize out, which dissolve completely in small quantities, but are decomposed by excess of water. When this decomposition ensues, a basic salt is deposited, while an acid salt remains in solution. A part of the former is redissolved on cooling, if free acid is present. Ammonia precipitates pure hydrated manganic oxide. (Berzelius.)

‡ A fluoride of manganese has been prepared, in which the Mn and F exist in the ratio 1 : 7 respectively. When a mixture of two parts potassic manganate or permanganate and one part fluor-spar is digested

* Gmelin, vol. iv. Manganese.

† Ibid.

‡ Wöhler, Pogg. 9, 619; Dumas, Ann. Chim. Phys., 36, 82.

with sulphuric acid in a platinum retort, a yellow vapor, purple in moist air, is evolved. This fluoride having the above ratio corrodes glass, and in so doing is resolved into (SiF_4) silicic fluoride and ($H_2Mn_2O_8$) permanganic acid. Chloride of calcium exposed to the yellow vapor evolves chlorine. The compound is absorbed by water, forming a purple solution, which contains hydrofluoric and permanganic acids. When the solution is evaporated in air, it evolves oxygen gas and hydrofluoric acid vapor, and leaves a brown residue from which water dissolves manganous fluoride, leaving a black insoluble basic salt. The solution dissolves copper, mercury, and silver, with formation of the corresponding fluorides.

* The tetrafluoride of manganese, MnF_4, is produced in solution: (1) when hydrofluoric acid is allowed to act on an ethereal solution of $MnCl_4$; (2) when the acid acts on MnO_2, in which case all the acid employed cannot be neutralized. The solution decolorizes indigo, and produces colors with anilin and naphthylamine; but may be preserved in the presence of glucose and gum-arabic. The substance dissolves in alcohol; decomposes in presence of much water, especially when it is alkaline, peroxide of manganese being formed. When potassic fluoride is added to the preceding solution, a rose precipitate is formed, which when dried at 100°C yields the formula $MnF_4 2KF$. Ammonic fluoride yields a compound of analogous composition. The alkaline fluorides appear to give stability to the tetrafluoride. The potash salt melts, and after lengthened fusion the salt $MnF_2.4KF$ is obtained. The solution of tetrafluoride precipitates an alcoholic solution of plumbic acetate. None of these compounds are crystalline. If to a boiling solution of potassic fluoride or ammonic fluoride perchloride of manganese is gradually added, a red powder comes down, the constitution of which is represented by the formula $MnOF_2$. This oxyfluoride and the preceding tetrafluoride are soluble in anhydrous ether. Under the same conditions as above the sesquifluoride of manganese acts in a similar manner, the properties of the compounds thus formed being generally the same. With $K_2Mn_2O_8$ and hydrofluoric acid, either one or other of the following bodies is obtained: $MnF_4.2KF$; Mn_2F_2O+2KF.

† When MnO_2 is treated with hydrofluoric acid, brown crystals are sometimes deposited, especially when the mixture has been digested with the aid of heat. The crystals when dried on paper furnish the

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* Bull. Chim. Soc. viii. 468, Nicklès.
† Ibid.

formula $Mn_3F_8 . 10H_2O$. The substance is soluble in a small quantity of water, but decomposed by an excess into the brown oxide of manganese. Its solution forms a red precipitate with potassic fluoride. Dissolves silver, and is decolorized in passing to the state of protofluoride.

* A fluosilicate of Mn has been artificially prepared, represented by $MnSiF_6 . 7H_2O$. Crystallizes in long six-sided prisms, and rhombohedrons. Color very light red. When heated, it first gives off seven molecules of water, then gaseous SiF_4, leaving MnF_2 of the same form as the original crystals. Easily soluble in water.

Manganous Fluoride, MnF^2.— Owing to the difficulty of obtaining manganous oxide free from higher oxides, it was found more practicable to prepare this fluoride by dissolving the white manganous carbonate in hydrofluoric acid. The resulting liquid was then evaporated on the water bath to dryness. The fluoride rendered anhydrous by drying at 100°C. gave by analysis : —

	Found.	At. Ratio.	Theory.
Mn	58.68	1.06	59.14
F_2	40.57	2.13	40.86
	99.25		100.00

Manganese and fluorine were separated by decomposition with a concentrated solution of potassic hydrate, the hydrate of Mn thus formed converted into pyrophosphate, and the fluorine in the filtrate precipitated as calcic fluoride.

Properties. — Color white, shading faintly into pink. Structure crystalline, but indistinct. Insoluble, or sparingly soluble, in water and alcohol. Decomposed by the fixed alkalis and their carbonates. Dissolves in mineral acids, but in no case evolves hydrofluoric acid vapor except when treated with concentrated sulphuric acid. (It may be well to notice once for all that concentrated sulphuric acid invariably decomposes fluorides with evolution of hydrofluoric acid.) Dissolves in water containing free HF. Not decomposed by water, or by exposure to air. At red heat fuses to a dark brown mass with loss of fluorine.

Manganous Fluoride and Hydrofluoric Acid, $MnF_2 . 3HF . 9H_2O$. — When the anhydrous MnF_2 is dissolved in aqueous hydrofluoric acid, and the solution evaporated in vacuo over sulphuric acid, crystals containing free hydrofluoric acid are deposited. Also prepared directly

* Gmelin, vol. iv. Mn. Berzelius.

from manganous carbonate. The crystals freed from hygroscopic moisture gave the following numbers: —

	Found.	At. Ratio.	Theory.
Mn	17.90	.32	17.46
F_5	29.16	1.54	30.16
H_3			.96 } 52·38
$9H_2O$			51.42 }
			100.00

The salt was dissolved in water, the manganese precipitated with a solution of sodic carbonate, and, after filtration, fluorine was thrown down by calcic chloride.

Properties. — Colorless, sometimes light pink. Crystals are transparent long prisms of the trimetric system. Soluble in water, giving acid reaction. Soluble in acids. Effloresces in air; when heated at 100°C., changes into the simple MnF_2.

Double Fluoride of Manganous Oxide and Potassium, MnF_2. KF. — On the addition of an excess of potassic fluoride to a solution of manganous chloride, an immediate separation of an insoluble compound results. A double decomposition ensues, which is expressed by the reaction: —

$$MnCl_2 + 3KF = MnF_2 . KF + 2KCl.$$

The precipitate collected on a filter is washed with water, then with alcohol, and subsequently with ether. Alcohol and ether are employed to remove the last traces of water. Heating at 100° produces the same result: —

	Found.	At. Ratio.	Theory.
Mn	36·23	·66	36·40
K	26·06	·66	25·87
F_3	37·71	1·98	37·73
	100·00		100·00

The method used in analysis was based upon the conversion of the double fluoride into a mixture of sulphates of manganese and potassium. The weight of the sulphates being known, as also that of the manganese therein contained, the percentages of the metals were easily calculated, while the fluorine was inferred by difference.

Properties. — Flesh colored. Crystalline. Insoluble in water and alcohol. Not decomposed in air and water. Dissolves in acids. Fuses at red heat.

This fluoride was first prepared by Gay-Lussac and Thenard, and afterwards described by Berzelius as a compound of manganese and potassium; but the latter established no ratio between the constituents.

An analysis of the soda salt which is precipitated under the same conditions will by analogy furnish the formula $MnF_2 . NaF$.

Another double fluoride of manganese and potassium has been obtained by adding potassic fluoride to a solution of $MnF_2 . 3HF$. A white crystalline precipitate is immediately thrown down, which analysis shows to contain Mn and K in the ratio 1 : 4 respectively. This double fluoride has identical properties with the preceding.

Tetrafluoride of Manganese, $MnF_4 . 4H_2O$. — (1) A black oxide of manganese was prepared by exposing manganous carbonate to a dull red heat for a considerable time. This oxide was proved to be Mn_2O_3: —

	Found.	At. Ratio.	Theory.
Mn_2	69.62	1.26	69.60
O_3	30.38	1.89	30.40
	100.00		100.00

This oxide dissolves readily in hydrofluoric acid with the aid of heat, and the deep red solution, when evaporated to the crystallizing point, deposits crystals on cooling. A larger crop of crystals is obtained by carrying the solution to dryness in vacuo. (2) Pure peroxide of manganese is dissolved in hydrofluoric acid under pressure with the aid of heat. On evaporating the solution red crystals are obtained.

In the following analysis, Mn was estimated, and the combined weight of fluorine and water inferred from the loss. The water was then determined in a second portion of the material by ignition with plumbic oxide. The fluorine was thus indirectly ascertained: —

	Found.	At. Ratio.	Theory.
Mn	27.22	.49	27·10
F_4	36.82	1.94	37·43
$4H_2O$	35.96	1.99	35·47
	100·00		100·00

Properties. — Color, red by reflected, purple by transmitted, light. Crystallizes in the monoclinic system in rather long, narrow prisms. These prisms consist in basal planes at the end of the ortho and klino

diagonals, and in four planes constituting a vertical dome; they terminate at one end in two planes which form one-half of a klino dome. Partially decomposed by large quantities of water and alcohol; completely by a solution of a fixed alkali into the brown hydrate of manganese and fluoride of the alkali. Soluble in acids; partially soluble in anhydrous ether. Insoluble in benzol and toluol. When the solution of this fluoride before crystallization is boiled, a dark brown substance is deposited, which evolves HF vapor with sulphuric acid. The crystals retain their crystalline form, but turn dark brown on exposure to air or the temperature of 100°C. This brown substance is probably an oxyfluoride, in which two or a multiple of two atoms of fluoride in the original fluoride are replaced respectively by one or more atoms of oxygen.

I can account for the formation of MnF_4 instead of Mn_2F_6 from the sesquioxide in no way except by assuming either that during the process of evaporation the sesquifluoride breaks up into tetrafluoride, or that the existence of a sesquifluoride is impossible.

Double Fluoride of Peroxide of Manganese and Potassium, $MnF_4 . 2KF$. — To a moderately concentrated solution of MnF_4, potassic fluoride dissolved in water is added in excess. Care must be taken that the solution of potassic fluoride is concentrated, otherwise the tetrafluoride of manganese will be decomposed. A rose-colored precipitate immediately separates, which when dried at 100°C. presents the following composition: —

	Found.	At. Ratio.	Theory.
Mn	22.00	.40	22.25
K_2	31.82	.81	31.65
F_6	46.18	2.43	46.12
	100.00		100.02

The analysis was conducted in the same manner as that of the former double fluorides.

Properties. — Rose colored. Under the microscope exhibits traces of crystalline structure; form indistinct. Decomposed by water, but not so readily as the tetrafluoride. Soluble in acids. Stable in air. Fuses to a blue mass, which on cooling resumes its original color.

A fluoride of manganese was prepared, in which the ratio between manganese and fluorine was found to be 1 : 8 respectively. This fluoride, however, requires further study; and it is hoped that, if the above ratio shall be proved beyond question to exist, the exact relation and disposition of the atoms will be determined.

Finely pulverized $K_2Mn_2O_8$ was dissolved in aqueous hydrofluoric acid, and the solution subjected under pressure to the temperature of 100°C two or three hours. The red solution was then evaporated in vacuo. Claret-red prisms belonging to the trimetric system were deposited, in which the ratio of the constituents — Mn, K, and F — was not determined. Consequently this substance also remains for future investigation.

XX.

ON SOME ALGÆ NEW TO THE UNITED STATES.

BY W. G. FARLOW.

Presented May 9, 1877.

THE present paper is a supplement to one presented to the Academy, March 9, 1875; and our object is to complete, as far as possible, the list of marine algæ found in the United States. We include a number of species which were referred to in a paper in the "Report of the United States Fish Commission" for 1875, which was intended to serve as a guide to the collection of algæ in the Government Building at the Centennial Exhibition. Some species of New England, which are soon to be described at length in another publication, are here mentioned only by name.

Of the species added to our marine flora, a number were collected at Key West and the Tortugas by Mr. F. W. Hooper, in the winter of 1876. New Californian species have been received from Dr. Anderson, of Santa Cruz; Mr. Cleveland; Mr. Hemphill, of San Diego; and Miss Lennebacker, of Santa Barbara. Several interesting forms were collected by Dr. Edward Palmer at the island of Guadeloupe and in the vicinity of San Diego, and Prof. D. C. Eaton, of New Haven, has kindly communicated species from both east and west coasts.

FLORIDEÆ.

DASYA SUBSECUNDA SUHR. K.tz. Tab. Phyc., V. XIV., Pl. 78 a. b. *D. Callithamnion* Harv. Farlow, Proc. Am. Acad., 1875. San Diego, Cleveland; Santa Barbara, Dr. Dimmock. This minute species, which is not uncommon in Southern California, has the habit of *C. Wurdemanni* Bail., but the ramuli are robust and more or less secund, while in *C. Wurdemanni* they are attenuated and dichotomous, branching at wide angles. We formerly erroneously referred this species to *D. Callithamnion* Harv., being led to that conclusion by the fact that a cross-section of the stem showed four cells around a central cell, as was also the case with an authentic specimen of *D. Callithamnion* Harv. Far-

ther study shows, however, that the number of cells seen in cross-section varies from four to eight; and it may be remarked that, in most of the species belonging to the subgenus *Stichocarpus*, the number of cells is too inconstant to constitute a specific character.

DASYA TRICHOCLADOS *Mert.* var. Oerstedi, *J. Ag.* = Dasya lophoclados Mont., Ner. Am. Bor. II. p. 65.

TÆNIOMA CLEVELANDII, n. sp. fronde capillaceâ erecto-cæspitosa ad 4 pollicares; ramis flexuosis irregulariter pluries pinnatis, ramulis ad basem contractis, ultimis subulatis incurvatis; articulis subcompressis, 4 siphoniis fere ecorticatis, 2 siphoniis lateralibus marginatis; stichidiis numerosis sparsis vittæformibus tetrasporas oppositas foventibus in apicem subacutum abeuntibus. — San Diego, Cal., Mr. D. Cleveland. — But two species of this genus are as yet known, *T. perpusillum* Ag., found by Liebmann on the west coast of Central America, and *T. macrourum* Thur., found by Schousboe at Tangier. We should naturally expect the first-named species to occur at San Diego; but, as it is described by Agardh as closely resembling *Callithamnion Rothii* in habit and mode of growth and having subfasciculate stichidia, it would hardly seem as though the plant collected by Mr. Cleveland, which has scattered stichidia, is four inches high, and has a striking resemblance to *Griffithsia tenuis* Harv., could belong to the same species. The specimen sent by Mr. Cleveland is unfortunately broken off near the base; but, judging from what was sent, there seems to be no creeping primary filament. From *T. macrourum* the present species differs in having the stichidial branches terminate in a more or less acute apex instead of two hairs. When seen in front view, the frond shows a series of articulations, each of which is composed of three subequal cells bordered on both sides by a wider cell. A cross-section is rather narrowly elliptic, and shows four subequal cells arranged round a central cell, as in many species of *Polysiphonia*; but each of the cells lying in the longer axis of the ellipse has a cell in contact with it on the outer side and of about the same size as itself, so that the short axis of the ellipse is composed of two, and the long axis of four, cells besides the central cell. In the lower part of the frond, the angles between the primary cells are filled with a small but irregular number of secondary cells.

POLYSIPHONIA SENTICULOSA Harv. This species, described in the Jour. Proc. Linn. Soc., Vol. VI. No. 24, p. 169, is apparently common along the whole Californian coast. It admits of question whether the species should not be considered a variety of *Pol. urceolata*.

POLYSIPHONIA SECUNDA Ag. Under this species is included by

Agardh *Polysiphonia pecten-Veneris, var. B.* Harv., of the Ner. Am. Bor. II., p. 46. The question then arises, What is the plant described in the Ner. Am. Bor. II., p. 35, as having but four siphons, and referred to *Polysiphonia secunda* Mont., said by Montagne himself, Syll. Crypt. p. 424, to be the same as *P. secunda* Ag.

Polysiphonia pennata Ag. To this species was doubtfully referred a small Polysiphonia from San Diego, which seemed not uncommon on *Gelidium cartilagineum* and other large *Florideæ*. The specimens should have more properly been referred to *Polysiphonia verticillata* Harv. A single specimen received from Mrs. T. M. Allen, collected at Santa Barbara, Cal., does not seem to belong either to *P. verticillata* or to *P. dictyurus*, if the figure in the Tab. Phyc. is to be trusted, and may belong to *Polysiphonia pennata.*

Polysiphonia thyrsigera J. Ag. Key West, Mr. F. W. Hooper; Nassau, Miss Minns.

Polysiphonia dictyurus J. Ag. San Diego, Cal., Mr. D. Cleveland. A single specimen, which we supposed to be new and to which we gave the manuscript name of *P. Clevelandii*, seems to be a variety of *P. dictyurus*, in which the ramuli are very regularly pinnate, and the ultimate ramuli all beautifully recurved. The number of cells in cross-sections of the larger branches is ten.

Acanthophora muscoides Ag. The true *A. Delilei* has never been found in this country. The species given by Harvey with that name, in the Ner. Am. Bor., is *Acanthophora muscoides*, Ag. and the name *A. Delilei* should have been suppressed in the Proc. Am. Acad., 1875.

Ricardia Montagnei Derbes. San Diego, Cal., Mr. Cleveland; Santa Barbara, Miss Lennebacker. This curious little plant is rarely over quarter of an inch high, and grows in small clusters on the concave tips of species of *Laurencia*. The Californian specimens on *L. virgata* resemble, in all respects, those from the Mediterranean, except that they are rather more luxuriant.

Laurencia Brongniartii J. Ag. Key West, Mr. F. W. Hooper. One of the more beautiful species of the genus, and which bears a striking resemblance to *Amansia multifida*.

Laurencia tuberculosa J. Ag. Prof. Agardh regards *Laurencia gemmifera* Harv., as a variety of this species.

Laurencia intricata Lam. Key West, Mr. F. W. Hooper. A species forming dense cushions, and resembling closely the figure in Kütz. Tab. Phyc., Vol. XV., tab. 61, was collected by Mr. Hooper.

Laurencia spectabilis, Post. & Rupr. Prof. Agardh is inclined

to keep this species distinct from *L. pinnatifida*, with which it was united by Harvey.

Erythrocystis Grevillei J. Ag. Epicr. = *Lomentaria ? saccata* J. Ag. Sp. p. 738.

Delesseria Woodii J. Ag. Santa Barbara, Cal., Miss Lennebacker.

Nitophyllum violaceum, J. Ag. Epicr. This is the species described in the Ner. Am. Bor. and Proc. Am. Acad., 1875, as *Nitophyllum laceratum* Grev.

Nitophyllum latissimum Harv. Under this species should be included *Nit. areolatum* Eaton mscr. of the Rep. U. S. Fish Comm., 1875.

Nitophyllum multilobum J. Ag. Epicr. Golden Gate, Cal., Berggren. We have never seen this species, which, according to Prof. Agardh, differs from all other species in having large transverse sori.

Nitophyllum spectabile Eaton. California.

Eucheuma acanthocladum J. Ag. Epicr. = *Chrysymenia acanthoclada* Harv.

Rhabdonia ramosissima J. Ag. Epicr. = *Chrysymenia ramosissima* Harv., Ner. Am. Bor.

The species of *Corallineæ* found on the coast of the United States are in a state of great confusion, and it will probably be some time before they are clearly made out. One great difficulty in the way is the uncertain characters by which the genera are at present constituted. In this connection, we only wish to call attention to the forms found on our coast, giving the names under which they are commonly described, without meaning to indorse the specific value assigned by different writers. We are greatly indebted to Dr. Ed. Bornet for notes and suggestions with regard to our species, especially the *Corallineæ* and *Squamariæ*.

Corallina pistillaris Mont. A small coralline, nearly related to this species, perhaps identical with it, has been found at Santa Cruz, Cal., by Dr. Anderson.

Amphiroa Orbigniana Harv. The common *Amphiroa* from California, which is usually distributed as *Amphiroa Californica*, D.cne., does not, according to Dr. Bornet, conform to the type of that species, but more properly belongs to *Amph. Orbigniana*. Harv. The species is incorrectly referred in Proc. Am. Acad., 1875, p. 364, to *Arthrocardia frondescens*, Aresch., to which some of the broader forms have a not very remote resemblance.

AMPHIROA VERTEBRALIS D.cne. This form, collected in Oregon by Rev. E. Hall, in 1871, resembles the species described by Postels and Ruprecht as *Amph. tuberculosa*, Illust. Alg., p. 20, T. XL. fig. 100, and it may be asked whether it is not really the same species.

AMPHIROA TRIBULUS Lam. A West-Indian species also found at Key West by Mr. F. W. Hooper.

AMPHIROA FRAGILISSIMA Lam. In the Ner. Am. Bor., Harvey mentions both *Amph. fragilissima* Lam., and *Amph. debilis* K.tg., as found at Key West. The *Amph. debilis* of Kützing is, however, only a synonyme for *Amph. fragilissima* Lam., while the plant referred to by Harvey is a much larger species, possibly *Amph. cuspidata* Lam.

LITHOTHRIX ASPERGILLUM. J. E. Gray. San Diego, Cal., Mr. Cleveland; Santa Barbara, Miss Lennebacker; Santa Cruz, Dr. Anderson. This species seems to be tolerably common along the California coast. It was quoted in the Rep. U. S. Fish Com., 1875, under the name of *Amphiroa nodulosa* K.tg. Judging from the figure in the Jour. Bot., 1867, there can be no doubt that this is the species there described; but it is difficult to understand the grounds for separating the genus *Lithothrix* from *Amphiroa.*

MELOBESIA AMPLEXIFRONS Harv. A species which appears common on *Zostera*, *Gelidium cartilagineum*, and other algæ from Santa Cruz, Cal., southward. The conceptacles are immersed so that the frond appears punctate.

MELOBESIA LENORMANDI Aresch. San Diego, Cal., Mr. D. Cleveland. A *Melobesia* occurs at Wood's Hole, Mass., which is probably also to be referred to this species.

MELOBESIA LEJOLISII Rosanoff. Common on *Zostera* at Nahant, Mass.

LITHOTHAMNION POLYMORPHUM Aresch. Very common from Boston northward, forming purple crusts on the rocks in tide pools. Also found at San Diego, Cal.

LITHOTHAMNION FASCICULATUM Aresch. Dredged in several places near Eastport, Me.

PETROCELIS CRUENTA Ag. Common on rocks from Nahant, Mass., northward; also at Santa Cruz, Cal. It has, as yet, been found only with tetraspores.

PEYSSONNELIA RUBRA (Grev.) J. Ag. The species referred to in the Rep. U. S. Fish Comm., 1875, under the name of *P. atro-purpurea* Crn., belongs more properly to *P. rubra.*

PEYSSONNELIA DUBYI Crn. San Diego, Cal., Mr. Cleveland. Although *P. rubra* is common at Key West, it is doubtful whether

P. Dubyi occurs there. We have also found sterile specimens of a *Peyssonnelia* at Eastport, Me., which is probably referable to *P. Dubyi*. *P. imbricata*, K.tg., in the absence of fruit, will remain a doubtful species.

CRUORIA PURPUREA, Crn. San Diego, Cal., Mr. Cleveland.

CRUORIELLA ARMORICA, Crn. San Diego, Cal., Mr. Cleveland.

GALAXAURA (MICROTHOE) LAPIDESCENS Lam. Key West, Mr. F. W. Hooper.

GALAXAURA RUGOSA, Kütz. Key West, Mr. F. W. Hooper.

Liagora farionicolor, and *L. Cayohuesonica* Melville, Jour. of Bot., Sept., 1875, do not seem to be admitted as species by Agardh in his Epicrisis.

NEMALION? ANDERSONII, n. sp. frondibus congregatis lubrico-cartilagineis simplicibus vel sparse furcatis; ramis primum subcompressis solidis demum cavis cylindraceis ad 6-8 pollicares altitudine, plerumque subæqualibus ramulis dense cinctis; ramulis simplicibus vel furcatis; antherozoideis ad cellulas externas fasciculatis; cystocarpiis? — Santa Cruz, Cal., Dr. C. L. Anderson. — This species, first found by Dr. Anderson, is variable in appearance. When young, the fronds are solid, and consist of an undivided axis, from which are given off short lateral branches in all directions. When older, the main axis forks once or twice, as do also the ramuli; and, still later, the main axis becomes swollen and hollow, and not unfrequently perforated. The substance is always lubricous and cartilaginous, and the color is a blackish-purple. The frond is composed of closely interwoven longitudinal filaments, from which are given off at right angles dichotomous moniliform filaments. We have never found the cystocarps or tetraspores of this species, and consequently there must remain some doubt with regard to the genus. Antherozoids are abundant, and nearly cover the surface of some specimens. As we have not been able to find traces of cystocarps, it is probable that the present species is diœcious, and, in that respect, different from other species of *Nemalion*. In aspect it not unfrequently resembles a coarse *Chordaria*, and in its later stages bears a certain resemblance to some forms of *Halosaccion ramentaceum*. As ordinarily seen, it is easily recognized by the rather thick main axis, closely beset with short ramuli of nearly equal length. The ramuli are often distorted by the parasite *Streblonema fasciculatum* Thuret. *Nemalion virens*, Ag., of the Pacific coast of Mexico, might be expected to occur in California. The description of that species, however, does not at all apply to the plant found by Dr. Anderson.

PLOCAMIUM VIOLACEUM, n. sp. fronde anguste lineari ad 5-6 pol-

licares altitudine irregulariter pinnata; ramis ecostatis præcipue ad apices flexuosis; pinnis alterne 2-4, plerumque 3, pinna inferiori subuliformi sæpe recurvata pinnas superiores decomposito-pinnatas superante; sphærosporis biseriatim ad 2-3 furcatos apices ordinatis. Color purpureus. — Santa Cruz, Dr. C. L. Anderson; San Diego, Mr. D. Cleveland. — The present species is said by Dr. Anderson to inhabit rather deep water. It resembles *Plocamium coccineum* in having the pinnæ arranged alternately in threes and fours, but differs in having the lower pinna larger than the others and slightly recurved. In the length of the lower pinna, the species approaches *P. cornutum* which, however, does not have pinnæ arranged in threes or fours. In the flexuous character of the branches, the species resembles *Pl. coccineum var. flexuosum* Harv., which is considered by Agardh a variety of *Pl. leptophyllum* Kütz. We have compared the present species with specimens of *Pl. coccineum var. flexuosum*, named by Harvey, and find it to differ in color and substance and in the large lower pinna. The plant adheres slightly to paper, and is of a dark purple color, unusual in species of the genus.

Cordylecladia conferta (Schousb.) Mont. San Diego, Cal., Mr. Cleveland; Santa Barbara, Miss Lennebacker. Not an uncommon species of Southern California, but sometimes distributed as a species of *Gracilaria*.

Sarcophyllis Californica J. Ag. In his Epicrisis, Prof. Agardh separates this species from *S. edulis*, to which species California specimens had been previously referred.

Farlowia crassa J. Ag. Santa Cruz, Cal., Dr. Anderson; Oregon, Rev. E. Hall.

Farlowia compressa J. Ag. Santa Cruz, Dr. Anderson; Santa Barbara, Miss Lennebacker; San Diego, Mr. Cleveland.

Cryptosiphonia Woodii J. Ag. Santa Cruz, Cal., Dr. Anderson.

Kallymenia Californica, n. sp. fronde carnosa radiatim prolifera demum irregulariter fissa inferiori parte costata; prolificationibus flabelliformibus in stipitem basi attenuatis sæpe phyllis marginalibus minutis fimbriatis; cystocarpiis in media fronde numerosis immersis. — Santa Cruz, Cal., Dr. Anderson.— This species was found by Dr. Anderson thrown up from deep water in company with *Constantinea Sitchensis*, which it resembles in texture and color. In fact, until the tetraspores have been discovered, it will not be possible to affirm that this is not a *Constantinea*, although the absence of a distinct stipe would lead one to place the plant in the genus *Kallymenia* rather than *Constantinea*. We first supposed the plant to be *Kallymenia? phyllophora*

J. Ag.; but having sent a specimen to Prof. Agardh, he has decided that it is not the species prevously sent him from Vancouver's Island. The fronds are fixed by a disk, from which they rise, or more probably expand out horizontally, for five or six inches. As most commonly seen, they resemble a spècies of *Opuntia* with fan-shaped or obovate joints, which are usually fringed with small leaflets on the margin. All the lower parts are distinctly costate. The color is a deep red, which becomes very dark. The cystocarps are densely scattered in the central part of the upper portion of the frond. In none of the specimens which we have received is the fruit ripe; but, using the common expression adopted in this order, there is a compound nucleus, not a simple one, as found in *Prionitis*, *Schizymenia*, and other allied genera.

PHYLLOPHORA CLEVELANDII Farlow. Tetraspores in oval shaped nemathecia in the upper part of frond.

GYMNOGONGRUS LEPTOPHYLLUS, Ag. California, Dr. Anderson. Under this name Prof. Agardh distinguishes the species commonly distributed as *Gymnogongrus Griffithsiæ* of our west coast, in which the cystocarps are immersed, or nearly so. There is still another *Gymnogongrus*, not uncommon in California, in which the cystocarps project hemispherically on one side of the frond, and which, with little doubt, is *G. tenuis*, Ag. *G. linearis* Ag. was accidentally omitted from the list in Proc. Am. Acad., 1875.

CHONDRUS CANALICULATUS Ag. California in several places. It is doubtful whether *C. affinis* Harv. is really distinct from this species.

CRYPTONEMIA OBOVATA J. Ag. Santa Cruz, Cal., Dr. Anderson.

CRYTONEMIA DICHOTOMA J. Ag. A single specimen of what seems to be this species was collected by Mr. D. Cleveland at San Diego.

PRIONITIS ANDERSONIANA, Eaton mscr. Santa Cruz, Dr. Anderson.

PRIONITIS? CLEVELANDII, n. sp. fronde coriacea substipitata repetite flabellatim prolifera inferiori parte subcostata demum irregulariter perforata; prolificationibus a disco aut intra marginem exeuntibus; cystocarpiis — ? — San Diego, Mr. D. Cleveland. — Of this striking species we have seen but a single sterile specimen, from which it is of course impossible to determine the genus with certainty. We at first supposed it to be the same as the plant to which we have given the name of *Kallymenia Californica*. The resemblance, however, is only external, for the structure of the frond is exactly that of *Prionitis*. If the fruit of the present species should show that it really belongs to

the genus *Prionitis*, it may be readily distinguished by its flabellate habit. In some respects, it resembles in form *Iridæa lacera*, Post. and Rupr. Ill., p. 17.

SCHIZYMENIA? COCCINEA Harv. Santa Cruz, Cal., Dr. Anderson; San Diego, Mr. Cleveland. To this species, described in Jour. Proc. Linnean Soc., Vol. VI., No. 24, is doubtfully assigned several large specimens from California.

GRATELOUPIA CUTLERIÆ, Binder. Santa Cruz, Cal., Dr. Anderson; San Diego, Mr. Cleveland. This very variable species has undoubtedly received several specific names, and it must be said that even *Gr. Gibbesii* Harv., of our southern coast, is not decidedly distinct. If one is to found species of *Grateloupia* on the outlines of the frond alone, it will be easy to make almost any number of species out of *Gr. Cutleriæ*.

HALYMENIA DECIPIENS, J. Ag. Key West, Mr. Hooper.

NEMASTOMA CALIFORNICA, n. sp. fronde gelatinosa roseo-purpurea tereto-compressa basi alternata irregulariter pinnata; pinnis pinnatis; pinnulis ultimis subuliformibus; cystocarpiis in corticali parte frondis numerosis. — Santa Cruz, Dr. Anderson; Santa Barbara, Miss Lennebacker. — This plant, which we formerly referred to *Halymenia ligulata* under the name of variety *Californica*, differs in the structure of the cortical filaments from any species of *Halymenia;* and granting that the genera *Halymenia, Nemastoma, Gloiosiphonia,* and *Calosiphonia*, are nearly related to one another, the present species, owing to the fact that the central siphon can be traced only at the tips of the branchlets, cannot well be included in *Gloiosiphonia* or *Calosiphonia*, nor in *Halymenia*, since the cortical filaments are not united into a membrane, as is more or less the case with the species of that genus. In aspect the plant resembles rather closely *Gloiosiphonia capillaris*, and some of the older specimens are not very unlike narrow forms of *Halymenia ligulata*. It seems to be a connecting link between the genera *Gloiosiphonia* and *Halymenia* as far as the structure of the frond is concerned. When freshly mounted, the species is of an agreeable purplish-rose color; but, as usually received from California, it is brownish, and distorted by too heavy pressure.

GRIFFITHSIA OPUNTIOIDES Ag. Santa Cruz, Cal., Dr. Anderson.

GRIFFITHSIA BORNETIANA Farlow. In the Ner. Am. Bor., Harvey refers the common *Griffithsia* of the North American coast to *Griffithsia corallina*, Ag., with some doubt, and describes a variety *globifera* and a variety *tenuis*. In his Epicrisis, Agardh adopts the manuscript name of Harvey, *G. globifera*, to designate the American species.

Harvey states, however, that his name, *G. globifera*, was only intended to apply to what he afterwards called a variety of *G. corallina*. We have ascertained by examination of the living plant, which is common in Long Island Sound, that there is but one species which comprises all the forms described by Harvey under the name of *Griffithsia* in the Ner. Am. Bor. The so-called var. *globifera* is merely the male plant, of which the terminal cell is enlarged and globose, and has the antherozoids borne in the form of a cap on the summit, in which respect it differs from any other species of the genus. The male plant is always shorter and stouter than the female plant. The var. *tenuis* of Harvey is usually tetrasporic, and the tetraspores are borne in whorls of several consecutive joints. In another place we shall have more to say on the present species; and we only need remark, in this connection, that, under *G. Bornetiana*, we include all the forms erroneously referred by Harvey in the Ner. Am. Bor. to *Griffithsia corallina*, and by Agardh in his Epicrisis to *G. globifera*, Harv., which was the name applied by Harvey himself to what is really only the male plant.

CALLITHAMNION LEJOLISEA, n. sp. fronde minuta repente ad nodos *Amphiroæ* parasitica; filis verticalibus superne nudis in parte inferiore ramulosis; antheridiis ovalibus ad ramos inferiores terminalibus; cystocarpiis (favellis) ad ramos inferiores terminalibus; sphærosporis triangulatim divisis in ramulis lateralibus terminalibus. This very small species of *Callithamnion*, which is seldom an eighth of an inch high, was found growing on the joints of an *Amphiroa* received from San Diego, Cal. It is probably not rare on the coast of California, but from its small size escapes detection. It resembles perfectly, except in the cystocarps, *Lejolisea Mediterranea*, which grows upon *Udotea flabellata*. In both species the frond is procumbent and attached by disk-like cells, and the erect filaments give off at the base a few lateral branches, upon whose tips the organs of fructification are borne. In both species the antheridia are oval, and the tetraspores tripartite and more or less clustered. In the one case, however, the fruit is a true favella, and the species must be considered a true *Callithamnion*, while in the other the fruit is more complicated, having a special covering, and with the spores arranged not in indefinite masses, but around a central placenta.

CALLITHAMNION DASYOIDES J. Ag. (*Call. ptilophora* Eaton mscr.). California.

CALLITHAMNION ARBUSCULA, var. *Pacificum*, Harv., Jour. Proc. Linn. Soc., Vol. VI., No. 24 = *C. Pikeanum*, Harv., Ner. Am. Bor. 11, p. 230.

CALLITHAMNION HETEROMORPHUM J. Ag. Califonia.

CHANTRANSIA EFFLORESCENS, Thuret. (*Callithamnion* Ag.). On *Rhodymenia.* Gay Head, Mass.

DESCRIPTION OF A NEW ALGA OF CALIFORNIA.

BY PROF. DANIEL C. EATON, OF YALE COLLEGE.

NITOPHYLLUM SPECTABILE, fronde subsessili, erecta, maxima, ecostata atque ut videtur avenia, oblonga, profunde pinnati-lobata; parte media duplo vel triplo latitudine loborum, sæpe in lobum terminalem magnam producta; lobis laciniisve crebris, patulis, liguliformibus sæpius integris, nunc apice lobatis vel profundius partitis, margine vix undulata, rarissime phylla minima obovata e margine vel e disco emittentibus; soris et coccidiis per totam frondem creberrime conspersis.

Hab. ad Sanctam Crucem, California: legit Anderson, Aug.–Sept. 1874.

Among the largest species of the genus, often two feet long, or even longer, and, in the spread of the lobes, two-thirds as broad. The lobes are so crowded as to overlap each other, and are 6-8 inches long and about an inch wide, lanceolate or strap-shaped, rather obtuse, mostly entire, but now and then two to three forked, or slightly dichotomously lobed. One specimen bears numerous minute obovate prolifications along the margin, and sparingly on the disk, especially where there has been some injury. No veins visible. The tetraspores are in oblong or irregular sori, thickly scattered all over the frond; and in the fruiting plant mature and young coccidia are sprinkled with almost equal profusion. The substance is rather firm, but thin, and not adhering very well to paper, except in the younger portions. I find but two layers of cells in the sterile portions of the lamina. The color is a dull purplish-red, more rosy in the newer portions.

XXI.

DESCRIPTIONS OF NEW SPECIES OF PLANTS, WITH REVISIONS OF CERTAIN GENERA.

By Sereno Watson.

Presented May 25, 1877.

Thelypodium Cooperi. Annual, erect or ascending, glabrous and glaucous, a foot high or more, rather lax and slender, sparingly branched: leaves oblong-lanceolate, an inch or two long, sessile, and cordate or auricled at base, acutish, entire: flowers on very short spreading or soon reflexed pedicels; sepals narrow, 1½ or 2 lines long, the narrow purplish petals a half longer: stamens included; anthers short: pods reflexed, 1 to 1½ inches long, subterete, beaked, on pedicels a line or two long.—Collected by Dr. J. G. Cooper near Fort Mohave in 1861, and referred to in Bot. Calif. i. 38; more complete specimens, gathered by Dr. Edward Palmer last season on the Mohave River, have been distributed under the above name.

LYCHNIS, Linn. The American species of this genus (conveniently retained as distinguished from *Silene* by the increased number of styles and carpels, though otherwise not to be separated from it) are more numerous than has been supposed. So far as known they may be arranged as follows:—

* Calyx clavate-oblong: capsule incompletely septate, 5-toothed.

1. L. alpina, Linn. Biennial or perennial, glabrous, slender, 2 to 10 inches high: leaves linear-oblanceolate: bracts somewhat membranous: flowers small, in capitate cymes: petals exserted, 4 or 5 lines long, 2-lobed: capsule shortly stipitate.—Greenland to Labrador. (Europe, Asia.)

* * Calyx more or less inflated: capsule not septate, 5–10-toothed: perennials.

+ Dwarf and cespitose, alpine or arctic: stems 1-flowered: seeds with a loose membranous margin: capsule very shortly stipitate.

++ Petals included, or nearly so.

2. L. APETALA, Linn. Glandular-pubescent above with short spreading hairs, sparingly so below, 3 to 8 inches high: leaves narrowly oblanceolate to linear, an inch or two long: flower nodding, or erect in fruit: calyx much inflated, 6 to 8 lines long, with short acutish teeth, strongly purple-veined: petals purple, the blade not broader than the claw, 2-lobed nearly to the middle; appendages very small; claw slightly auricled (not 1½ lines wide), naked.—Aleutian Islands and about Behring Straits; Greenland. (Europe, Asia.)

Var. GLABRA, Regel. Wholly glabrous.—Rocky Mountains of British America, by Bourgeau; St. Paul's Island, H. W. Elliott.

3. L. MONTANA. Glandular-pubescent above with short spreading hairs, nearly glabrous below, slender, 2 to 4 inches high: leaves linear-oblanceolate, an inch or two long, the petioles somewhat ciliate; flowers erect: calyx ovate-campanulate, 5 or 6 lines long, with short acute teeth: petals with the emarginate blade not broader than the very narrow claw (not ½ line broad); appendages very small: seeds rather broadly margined.—*L. apetala*, Gray in Am. Journ. Sci. 2 ser. xxxiii. 405, and Proc. Acad. Philad. 1863, 58, in part; Watson, King's Rep. 36. Mountain peaks of Colorado (n. 132 Parry, 63 Hall & Harbour), and in the Uintas (n. 152 Watson).

++ ++ Petals exserted.

4. L. AFFINIS, Vahl. Glandular-pubescent throughout, 3 or 4 inches high: leaves linear, an inch long or less, ciliate at base: flowers erect: calyx ovate-campanulate, 4 lines long, with short acutish teeth: petals 6 lines long, the blade undulate, emarginate, narrowing from near the top (1½ lines wide) to the base of the naked claw; appendages small, toothed.—Greenland to Labrador. (Europe, Asia.)

5. L. KINGII. Resembling the last, covered throughout with a short spreading pubescence: leaves linear-oblanceolate, 1 to 1½ inches long: calyx 6 lines long: petals with the short flat blade rather deeply emarginate; appendages entire or toothed; claw ciliate, rather broadly auricled: filaments ciliate.—*L. Ajanensis ?*, Watson, King's Rep. 37, but quite distinct from that Asiatic species. Peaks of the Uintas at head of Bear River; apparently also in Northwestern Wyoming (n. 43 Parry), but with a shorter calyx and petals, and naked filaments.

+ + Flowers rarely solitary: seeds tuberculate.

++ Low, arctic or alpine.

6. L. TRIFLORA, R. Brown. Rather stout, glandular-pubescent throughout, 2 to 9 inches high: leaves thickish, narrowly oblanceolate,

an inch long: flowers usually 2 or 3 together, nearly sessile, erect: calyx much inflated, densely pubescent, 5 or 6 lines long, with short rounded teeth, purplish and strongly veined: petals light rose-color, 7 or 8 lines long; blade narrowly obcordate, nearly 2 lines broad; appendages rather prominent, entire; claw narrowly auricled.—Greenland, from Polaris Bay (Dr. Bessel) southward.

7. L. CALIFORNICA. Slender, cespitose, glandular-puberulent above, nearly glabrous below, 2 to 4 inches high, deep green: leaves linear to linear-oblanceolate, an inch or two long, ciliate at base: flowers 1 to 3, on slender pedicels: calyx ovate-campanulate, 4 or 5 lines long, deeply toothed, the teeth ovate-triangular, acutish: petals about 7 lines long, the obovate blade bifid, lobed on each side near the base; appendages prominent, entire or toothed; claw broadly auricled, the auricles prolonged upward: capsule shortly stipitate: styles sometimes only 3 or 4.—In the high Sierra Nevada; near Ebbett's Pass (n. 2081 Brewer), on Mount Dana (H. N. Bolander), and in Sierra or Plumas County, J. G. Lemmon.

++ ++ Taller, not alpine nor arctic.

= Petals included or nearly so.

8. L. DRUMMONDII, Watson. Stems strict and rather stout, a foot or two high, finely glandular-pubescent above: leaves narrowly oblanceolate, 2 or 3 inches long, erect: flowers few, erect, on stout often elongated strictly erect pedicels: calyx cylindric, becoming oblong-ovate, 5 or 6 lines long, with short acutish teeth: petals rarely slightly exserted, white or purple, the entire or emarginate blade narrower than the auricled (a line wide) claw; appendages minute: capsule nearly sessile.—King's Rep. 37; *Silene Drummondii*, Hook. Fl. i. 89; *L. apetala*, Gray, l. c., in part. Winnipeg Valley and on the Saskatchewan, and in the mountains to New Mexico and S. Utah.

= = Petals long-exserted.

9. L. NUDA, Watson, l. c. Slender, finely pubescent, a foot high: leaves narrowly oblanceolate, 2 or 3 inches long: flowers on slender pedicels, nodding, at length erect: calyx 4 to nearly 6 lines long, cylindric becoming ovate-oblong, with rather narrow acutish teeth: petals white or rose-colored, 8 lines long, the broad limb 2-parted with the segments deeply bifid, the lobes irregular and mostly acute; appendages ovate, entire, thickish; claw broadly auricled, margined to the base: capsule nearly sessile.—East Humboldt Mountains, Nevada.

10. L. PARRYI. Slender, finely pubescent, glandular above, a foot high or less: leaves linear, an inch long or more: flowers erect

or somewhat nodding, the lateral pedicels mostly short: calyx inflated, ovate-oblong, 6 lines long, with broad acutish teeth: petals purplish, 8 lines long, the broad blade cleft to the middle (the rounded segments entire, crenate, or bifid) and with a short narrow lobe on each side; appendages quadrate or ovate, thin and crenate; claw broadly auricled, very narrowly attenuated below: stipe of capsule a line long or more.—Northwestern Wyoming, collected by Dr. C. C. Parry on the expedition of Capt. W. A. Jones to the Yellowstone in 1873.

11. L. ELATA. Tall and slender, finely pubescent, slightly glandular above, 1½ feet high or more: leaves narrowly oblanceolate, 2 to 4 inches long, acute or acuminate: flowers nodding or erect, on slender pedicels: calyx inflated, ovate-oblong, 6 or 7 lines long, with triangular acutish teeth: petals purplish, 9 to 12 lines long, the blade cleft to the middle, with a narrow shorter lobe on each side; appendages broad, toothed; claw not auricled, attenuate to a very narrow base: stipe of capsule nearly 2 lines long.—Collected in the Rocky Mountains of British America by Bourgeau in 1858, and distributed as *Silene Scouleri*.

LAVATERA INSULARIS. A stout perennial, probably woody at base, finely stellate-pubescent: leaves with a narrow sinus, 3 to 6 inches broad, 7-lobed to the middle; the lobes rounded and obtuse, coarsely crenate: flowers solitary in the axils, on stout deflexed and curved pedicels nearly an inch long and with one or two small bractlets or naked: involucre of three nearly distinct oblong-spatulate acutish bracts, 6 lines long: calyx 5-cleft to the middle with broadly ovate acute lobes, becoming an inch long in fruit: petals spatulate and unguiculate, emarginate, naked at base, apparently purplish yellow with the claw darker, 1½ inches long: styles not exserted: fruit half an inch broad, slightly pubescent, about 10-carpelled, the sides of the carpels smooth.—Received from D. Cleveland, Esq., of San Diego, and collected on the Coronados Islands, 20 miles distant from that town. Like the following, it differs from the two previously known California species in the nearly distinct bracts of the involucre.

LAVATERA VENOSA. Similar in habit to the last, glabrous or nearly so: leaves 3 to 4 inches broad, 7-cleft to the middle with triangular acutish lobes: flowers two or three in the axils, on slender ascending naked pedicels 1 to 1½ inches long: involucre of 3 nearly distinct oblong-ovate acutish bracts, equalling the calyx, 3 or 4 (becoming 7) lines long: petals 15 lines long, cuneate-obcordate, deep purple with darker veins, villous on each side at base: styles long-exserted: fruit 5 lines broad, glabrous, about 10-carpelled: sides of the

carpels strongly veined.—From San Benito Island, off the coast of Lower California; collected by Dr. T. H. Streets, U. S. N., December, 1875. This is the fourth species of the genus that has been found on the small islands near the southern coast of California, and is peculiar in the prominent veins upon the sides of the carpels.

MALVASTRUM PALMERI. A stout perennial, densely stellate-pubescent and -hirsute: leaves broadly ovate, 2 or 3 inches long, somewhat 3–5-lobed, the lobes obtusish, crenately toothed; stipules conspicuous, broadly lanceolate, acuminate, nearly half an inch long: floral bracts large and conspicuous: flowers nearly sessile, in terminal clusters, large (1½ inches broad), yellowish rose-color: bractlets linear-lanceolate, 8 to 10 lines long, nearly equalling the acuminate calyx-lobes: carpels rounded, somewhat pubescent.—At Cambra in Southern California, a mile from the sea-beach; collected by Dr. E. Palmer (n. 50 of his distribution), July, 1876. Marked by its stout leafy habit and by its large floral bracts and calyx.

LUPINUS TRIFIDUS, Torrey in herb. Very closely resembling *L. micranthus*, but the lower lip deeply 3-cleft with linear segments: pod narrower and shorter (about 6 lines long and 1½ broad), usually 5–6-seeded: seeds a line broad, uniformly mottled: flowers 3 lines long or less, mostly in a single terminal whorl.—*L. micranthus*, var. *trifidus*, Watson, Rev. Lup. 535. Near San Francisco, by various collectors, and recently in fine specimens by Mr. G. R. Vasey. The ordinary *L. micranthus*, besides the nearly entire lip, has a pod often an inch long and 2½ lines broad, 6–9-seeded, and the larger seeds variously mottled, but with a lighter spot around the sometimes dark eye.

LUPINUS ARIZONICUS. Annual, slender, erect, a foot high or less, villous throughout with scattered spreading hairs: leaflets 6 to 8, shorter than the slender petioles, linear-oblanceolate, obtuse or acute, a half to an inch long: flowers scattered in loose racemes; bracts long and somewhat persistent: calyx rather broad at base, the lower lip trifid: petals 4 or 5 lines long, deep purplish blue or sometimes ochroleucous, the broad wings (2½ lines wide) exceeding the orbicular standard: pod 6 to 9 lines long, 3–6-seeded: seeds rounded, compressed, with prominent sides and rather thin margin, 1½ lines broad, nearly white.—*L. concinnus*, var. (?) *Arizonicus*, Watson, Rev. Lup. 537. In Arizona and South-eastern California. The typical *L. concinnus*, Agh., is much more densely villous, lower and of more diffuse habit; leaflets broader; calyx narrow at base, and flowers narrower (wings 1½ lines broad, and standard elliptical), the petals usually becoming reddish purple, or the standard yellowish: pods 3–4-seeded, but seeds similar.

PSORALEA CALIFORNICA. Stems very short and clustered, from tuberous (?) roots: pubescence short, silky, appressed: leaves digitately 5-foliolate, the leaflets broadly oblanceolate, acutish, 9 to 15 lines long; stipules lanceolate, scarious and deciduous: peduncles shorter than the petioles: flowers on slender pedicels, in a short raceme: calyx silky-villous, half an inch long, the linear acuminate lobes a little exceeding the persistent petals: pod very thin, somewhat villous, beaked: seeds smooth, compressed and rather thin, 2 to $2\frac{1}{2}$ lines long.—At McGinnis' Ranch, near head of Salinas River, 25 miles from San Luis Obispo, California; collected by Dr. Edward Palmer, July, 1876, in mature fruit. Resembling in habit *P. esculenta* of the eastern plains.

LYTHRUM BREVIFLORUM. Much branched, with the habit of narrow-leaved forms of *L. alatum*, the long slender branches flower-bearing their whole length: calyx strongly striate, nearly 2 lines long in fruit, exceeding the narrow bracts, shortly pedicellate: petals 6, purple, a line long or more: stamens 6 or 8: seeds minute, round-ovate, somewhat compressed.—*L. alatum*, var. (?) *breviflorum*, Gray in Pl. Lindh. 187 (n. 609 Lindheimer, 1847, in part). On damp rocks in the Guadalupe River, Texas. The seeds of *L. alatum* are linear-oblong and twice longer.

ŒNOTHERA (TARAXIA) PALMERI. A dwarf cespitose annual; branches very short, stout, covered with a loose white epidermis: leaves lanceolate or oblanceolate, an inch or two long, pubescent, ciliate, entire or nearly so: calyx-tube filiform, nearly equalling the leaves: petals yellow, 2 lines long: capsules crowded, ovate, 3 or 4 lines long, quadrangular at base, acute and strongly winged above, dehiscing along the truncate upper edge of the wings: seeds lanceolate-ovoid, terete, $\frac{3}{4}$ line long, nearly smooth.—Collected in Arizona by Dr. Edward Palmer, 1876.

ŒNOTHERA TRILOBA, var. (?) PARVIFLORA. Flowers very small, not more than an inch or two long, fertilized in the bud, and rarely fully opening: fruit abundant, forming at length a densely crowded hemispherical or cylindrical mass, nearly 2 inches in diameter and often 2 or 3 inches high. — A curious form of this very variable species, or possibly distinct, frequent in buffalo-wallows in the neighbourhood of Ellis, Kansas, where it has been collected by Dr. Louis Watson. It is also found in previous collections, and is probably common on the plains of Kansas and Nebraska in like localities. Under cultivation in the Botanic Garden, Cambridge, it has retained its peculiarities as respects the manner of flowering. It is strictly an annual, coming early into bloom. The capsules are rarely over a half inch long,

less attenuate above and smaller than is usual in the ordinary large-flowered state of the plant.

MENTZELIA HIRSUTISSIMA. Stout, erect, with ascending branches, very hirsute with spreading rigid hairs in addition to the usual barbed pubescence: leaves linear-lanceolate, 1½ to 3 inches long, acuminate, irregularly pinnatifid with divaricate acute segments and teeth; lobes of the floral leaves very narrow: flowers terminal, sessile: calyx-limb deeply 5-cleft, 8 to 12 lines long, the lanceolate lobes long-acuminate: petals yellow, acute, 1½ inches long: filaments very numerous, orange-colored above, shortly cuspidate on each side of the anther, nearly ½ inch long, shorter than the style: capsule oblong, ½ inch long.—Angels Island, in the Gulf of California; Dr. T. H. Streets, U. S. N., February, 1876. With *M. tricuspis* forming a section distinct from § *Bartonia*, characterized by the filaments dilated and bicuspidate above; style tubular and terete, 3-cleft at the summit (sometimes twisted); seeds (in *M. tricuspis*) in one row on each thin placenta, horizontal, not margined, irregularly flattened, coarsely and irregularly rugose, opaque and very minutely and densely tuberculate.

ELATERIUM MINIMUM. Stems very slender, almost filiform, a foot or two long, glabrous or nearly so: leaves thin, smooth above, white-papillose and scabrous beneath, triangular-cordate and more or less deeply hastate-lobed, 1 to 1½ inches broad, the lobes entire or somewhat serrate: the sterile raceme little exceeding the leaves; limb of the flowers 4 lines broad: fertile flowers on slender pedicels 1 to 6 lines long, the limb 3 lines broad, and the slender tube 2 lines long: fruit very small (4 lines long), acute at each end and beaked above by the persistent calyx-tube, echinate with spine-like processes, 2-celled and bursting irregularly on each side near the top; cells 3-ovuled, mostly 1-seeded: seeds oblong-ovate, 1½ lines long, compressed, dark-colored.—*Marah minima*, Kellogg, Proc. Calif. Acad. ii. 18. On Cerros Island, off Lower California (Dr. J. A. Veatch, Dr. T. H. Streets), and at Cape St. Lucas, L. J. Xantus.

ELATERIUM BIGELOVII. Very similar: leaves more decidedly hastate, the middle segment lanceolate, acute and cuspidate, the lateral ones 2-lobed, all entire or obscurely sinuate: staminate panicles shorter than the leaves: flowers smaller; limb less than 2 lines broad: ovary smooth, seemingly 1-ovuled: fruit unknown.—In the Lower Colorado Valley, Dr. J. M. Bigelow and Dr. E. Palmer. Referred to *Melothria pendula* in the Botany of California.

ANGELICA LEPORINA. Tall and stout in the manner of the genus, glabrous: leaves bipinnate; leaflets linear-lanceolate, acuminate, entire

or coarsely few-toothed, 1 to 3 inches long: umbels naked, the rays very unequal and somewhat scabrous: fruit small (about 1½ lines long); dorsal ribs prominent; oil-tubes solitary or the lateral in pairs.—Rabbit Valley, S. Utah; collected by L. F. Ward on Col. J. W. Powell's Exploring Expedition. Distinguished from our only other narrow-leaved species (*A. leanariloba*, Gray) by the very much shorter fruit.

MIRABILIS GREENEI. Very stout, with the habit of *M. multiflora*, somewhat glandular-puberulent: leaves rather thick, ovate, acute, attenuate to a short stout petiole, 3 inches long: involucre 7–10-flowered, acutely lobed, 1 to 1½ inches long: perianth tubular-funnel form, a half longer than the involucre, greenish purple: fruit ovate-oblong, usually abruptly contracted near the base, rather strongly 5-angled, the sides somewhat ridged longitudinally and more or less tuberculate, 3 lines long or more.—On mountain sides about Yreka, California; in flower and fruit, June, 1876; Rev. E. L. Greene. The fruit approaches that of an *Oxybaphus*.

ABRONIA MICRANTHA, Torrey, Frem. Rep. 96, and Marcy's Rep. t. 18 (as *A. cycloptera*). Prostrate: peduncles shorter than the petioles: flowers small and inconspicuous, 3 or 4 lines long, reddish green, the limb scarcely 2 lines broad: fruit orbicular with three thin wings, emarginate above and below, 8 to 10 lines wide, the body rather broad and with a light spongy exterior.—Frequent on the plains from the Saskatchewan to the Arkansas and S. W. Colorado, and well represented in the figure of Marcy's Report, excepting the limb of the perianth. *A. cycloptera*, Gray (Am. Journ. Sci. 2 ser. xv. 319, excl. syn.), with which it has been confounded, is a more southern species of Western Texas, New Mexico, and S. Colorado, of stouter habit, and with large showy flowers upon elongated peduncles. The fruit has a firmer and more prominently veined wing, emarginate at neither end, the firm smooth narrow body 7 to 12 lines long and usually 3-nerved between the wings. The third species of the section, *A. Crux-Maltæ*, Kellogg (Proc. Calif. Acad. ii. 71, fig. 16), of Western Nevada, with very showy flowers upon peduncles about equalling the leaves, has a smaller orbicular-winged fruit (5 or 6 lines in diameter), the ovate body pubescent and coarsely reticulate-pitted.

RUMEX OCCIDENTALIS. Tall and rather slender, often 3 to 6 feet high: leaves oblong-lanceolate, the lowest sometimes ovate, usually narrowing gradually upward from the truncate somewhat cordate base, not decurrent on the slender often elongated petiole, acute, a foot long or more, scarcely undulate: panicle narrow, elongated, nearly leafless:

pedicels filiform, 3 to 6 lines long, obscurely jointed near the base: valves without grains, broadly cordate with a very shallow sinus, becoming about 3 lines in diameter, often denticulate near the base: akene a line and a half long. — From Alaska to Northern California, eastward to the Saskatchewan and Labrador, and southward in the mountains to Colorado and New Mexico. It has hitherto been referred to *R. longifolius*, DC., but that Old World species has narrow and very undulate leaves, broadest near the middle, the pedicels with a tumid joint below the middle, and the valves more deeply cordate.

ERIOGONUM, Michx. During the seven years that have elapsed since the thorough revision of the *Eriogoneæ* by Dr. Gray, published in the eighth volume of these Proceedings, so much additional material has been collected and so many new species have been described that it seems not useless to give again a summary of the two larger genera of the group. Some modifications are made in the arrangement of the species in *Eriogonum*, based mainly upon the characters of the bracts and involucres, by which the genus is divided naturally into three principal sections, as follows: —

§ 1. Involucres not nerved or angled, 4–8-toothed or -lobed, more or less broadly turbinate (mostly 2 lines long or more): bracts foliaceous, indefinite in number (2 to 5 or more), rarely somewhat ternate. Mostly perennial. — EUERIOGONUM.

* Tall perennials with scarcely branching caudex, more or less villous-pubescent or silky, with long oblanceolate alternate leaves and alternate branches, loosely di- or trichotomous above: bracts small: involucres pedunculate, solitary, with 5 erect teeth: akenes large (2 to 4 lines long): embryo straight and axile.

+ Akenes membranously winged: flowers not attenuate at base, nor much enlarged in fruit. — (§ ALATA, Benth., excl. sp.)

1. E. ALATUM, Torr. Loosely silky-villous throughout, or the leaves nearly glabrous except on the margin and midrib: flowers a line long, yellow, nearly glabrous, abrupt at base: akene winged the whole length, 3 lines long. — Nebraska to W. Texas and Arizona.

2. E. TRISTE, Watson, Proc. Am. Acad. x. 347. Similar, but nearly glabrous: flowers deep purple, glabrous, somewhat narrowed at base: akene 4 lines long. — S. Utah.

3. E. HIERACIFOLIUM, Benth. Hoary-pubescent throughout and leaves usually tomentose beneath: flowers pubescent, yellow or rose-colored, 1½ lines long (or 2 lines in fruit), abruptly narrowed at base: akenes 2½ lines long, winged above the middle. — W. Texas and Rio Grande Valley.

+ + Akenes not winged: flowers attenuate at base, enlarging in fruit. — (sp. of § ERIANTHA, Benth., Torr. & Gray.)

4. E. LONGIFOLIUM, Nutt. Hoary-pubescent throughout and the leaves tomentose beneath: involucres and flowers densely white-silky: flowers mostly herbaceous, 1½ becoming 2 or 3 lines long: akene 2 lines long, pubescent above. — Indian Territory and Texas; Florida.

* * Tomentose perennials, with radical leaves, and naked scapelike stem, di- or trichotomous above, with large conspicuous bracts: involucres solitary, sessile, with 5 erect teeth: flowers attenuate to a stipelike base, pubescent, enlarging in fruit: akene mostly smaller: embryo straight and axile, or nearly so. — (§ ERIANTHA, Benth., Torr. & Gray, excl. sp.)

5. E. TOMENTOSUM, Michx. Tall, herbaceous, rufous-tomentose: radical leaves elongated, oblanceolate-spatulate; bracts elliptical, sessile, smooth above undulate: flowers white, tomentose, 2 lines becoming 4 or 5 lines long, the inner sepals largest: akene 2½ lines long. — S. Carolina to Florida.

6. E. UNDULATUM, Benth. A little-known Mexican species, described as low and cespitose, woody, much branched and leafy: leaves and bracts ovate, petioled, with revolute undulate margins: flowers much smaller.

7. E. JAMESII, Benth. Rather slender, herbaceous, with branching caudex, a foot high or less, white-tomentose: leaves and bracts oblong-oblanceolate, the latter shortly petiolate: flowers whitish, silky, 2 becoming 3 or more lines long: akene 2 lines long. — Var. FLAVESCENS. Stouter; flowers yellow or yellowish. *E. flavum*, var. *vegetius*, Torr. & Gray, Rev. 156. — Colorado to New Mexico and W. Arizona. The variety is distinguished from the next by the strictly solitary sessile involucres.

* * * Perennials, more or less tomentose or rarely glabrous, with peduncles naked and scapelike or verticillate-bracteate in the middle: bracts mostly conspicuous: involucres 5–8-toothed or -cleft, in a simple or compound umbel (rarely sub-capitate) or solitary: flowers mostly attenuate to a stipelike base: akenes glabrous or nearly so (2 lines long or less): embryo mostly somewhat curved and excentric (as in the rest of the genus). — (§ UMBELLATA, Benth., in part. §§ UMBELLATA & PSEUDO-UMBELLATA, Torr. & Gray.)

+ Teeth of involucre short, erect or nearly so.

++ Umbel simple (compound in n. 13), on a naked peduncle.

= Flowers villous.

8. E. FLAVUM, Nutt. Tomentose throughout, a span high or less; caudex branching: leaves oblanceolate: umbel of 3 to 9 rays, often short: flowers yellow, 2 or 3 lines long, long-attenuate at base, very

silky. — Washington Territory to the Saskatchewan and south to Colorado.

9. E. ANDROSACEUM, Benth. Dwarf, tomentose throughout or smoother above; caudex branching: leaves oblanceolate: rays short, slender: flowers yellow, 2 or 3 lines long, short-attenuate, sparingly villous. — Rocky Mountains of British America.

10. E. PYROLÆFOLIUM, Hook. Dwarf, somewhat villous; caudex simple: leaves round-obovate to oblong, thick: rays few, very short: flowers rose-color, 2 lines long, short-attenuate, sparingly villous. — Var. CORYPHÆUM, Torr. & Gray. More tomentose, with narrower leaves and smaller flowers. — Mountains, N. California and Oregon.

= = Flowers glabrous: caudex diffusely branched. — In the Sierra Nevada.

11. E. INCANUM, Torr. & Gray. Somewhat cespitose, tomentose, low: leaves oblanceolate, shortly petioled: bracts and involucres small: flowers yellow, often reddish.

12. E. MARIFOLIUM, Torr. & Gray. Low and very slender, diffusely branched below, tomentose: leaves ovate to oblong: bracts and involucres (a line long) small: flowers yellow or yellowish.

13. E. URSINUM, Watson, Proc. Am. Acad. x. 347. Taller and stouter, tomentose, villous above: leaves ovate: bracts elongated: umbel compound: involucres large: flowers whitish.

++ ++ Involucres solitary: peduncle verticillate-bracted in the middle: dwarf.

14. E. KELLOGGII, Gray, Proc. Am. Acad. viii. 293. Very slender, much branched at base, villous-tomentose: leaves oblanceolate, 2 to 4 lines long: flowers glabrous, white or rose-colored, 1½ to 2½ lines long. — Mendocino Co., California.

15. E. THYMOIDES, Benth. Densely branching and woody, with revolute linear leaves 1 to 5 lines long: peduncles slender: flowers densely villous with long hairs, purplish, 2 or 3 lines long, with broad sepals. — Oregon and Washington Territory.

+ + Involucres deeply lobed; lobes becoming reflexed.

++ Flowers pubescent: involucres solitary (rarely umbellate in n. 18), on verticillate-bracted peduncles (naked in n. 16): low, cespitose, with yellow flowers, and leaves tomentose both sides.

16. E. CÆSPITOSUM, Nutt. Dwarf, densely matted: leaves ovate- to oblong-spatulate, 2 to 6 lines long: peduncles naked. — N. W. Nevada to Wyoming Territory.

17. E. DOUGLASII, Benth. Larger and more diffuse: peduncles with a whorl of oblanceolate leaves in the middle. — N. California, Oregon.

18. E. SPHÆROCEPHALUM, Dougl. Similar, but still more diffuse: leaves linear-spatulate, often revolute: the whorl of bracts on the peduncle sometimes subtending a 2–4-rayed umbel, the lateral rays also bracteate. — N. California and Nevada, to Washington Territory.

++ ++ Flowers glabrous: umbels simple or compound, on naked (rarely 1-bracted) peduncles (verticillate-bracted in n. 22): caudex diffusely branched: leaves glabrate above or glabrous, oblanceolate or spatulate.

19. E. UMBELLATUM, Torrey. Tomentose: umbel simple, of 3 to 10 naked rays. — Var. MONOCEPHALUM, Torr. & Gray. A reduced dwarf alpine form, the naked or bracteate peduncle bearing a solitary involucre: leaves small. — N. California and Oregon to Colorado; common.

20. E. TORREYANUM, Gray. Glabrous throughout: umbel of few rays, the lateral rays bracteate in the middle and often divided: flowers large. — In the Sierra Nevada.

21. E. STELLATUM, Benth. Tomentose: rays 2 to 4, usually and often repeatedly cymosely divided: the nodes and lateral rays all leafy-bracted. — *E. ellipticum*, Nutt. *E. polyanthum*, Benth., Torr. & Gray. — Var. BAHIÆFORME. Umbel very compound: leaves mostly small, often densely tomentose both sides. — Oregon to S. California and Arizona.

22. E. HERACLEOIDES, Nutt. Similar, but the peduncle usually verticillate-bracted: leaves narrower, mostly somewhat revolute or undulate: umbel about 6- (1–11-) rayed, usually some or all of the rays once or twice divided. — Washington Territory to Utah.

++ ++ ++ Flowers glabrous: umbels usually compound, on naked peduncles: caudex short and thick: leaves round to oblong, tomentose.

23. E. COMPOSITUM, Dougl. Leaves oblong-ovate, cordate: peduncle stout and tall: umbel compound, of 6 to 10 elongated rays. — Washington Territory and Idaho to N. California.

24. E. LOBBII, Torr. & Gray. Leaves oval or rounded: peduncles short, decumbent: rays few, usually very short and undivided: flowers less attenuate at base. — In the Sierra Nevada.

* * * * Perennials, densely tomentose, with naked peduncles: bracts small: involucres with 5 short erect teeth: flowers small, abruptly narrowed at base, pubescent: akenes densely villous. — (LACHNOGYNA, Torr. & Gray.)

25. E. ACAULE, Nutt. Very dwarf and densely matted: leaves crowded, 2 or 3 lines long, oblong: peduncle half an inch high, bearing a head of 1 to 5 nearly sessile involucres. — S. Idaho to S. W. Colorado.

26. E. LACHNOGYNUM, Torr. Cespitose: leaves oblong-lanceolate: the slender peduncle a foot high, sparingly dichotomous above: involucres solitary, sessile or long-pedunculate: flowers densely tomentose: akene attenuate above, 2 lines long. — S. Colorado and New Mexico.

* * * * * Perennial, villous, dwarf, with naked peduncles bearing a subcapitate umbel: bracts conspicuous: involucres campanulate, 4–8-parted, with erect somewhat unequal lobes: flowers abruptly attenuate at base, villous: akenes glabrous.

27. E. VILLIFLORUM, Gray, Proc. Am. Acad. viii. 630. Densely cespitose, very villous throughout, the crowded oblanceolate leaves half an inch long: peduncles slender, an inch high: bracts linear: involucres few in the loose heads, bracteate at base, the slender pedicels a line long: flowers $1\frac{1}{2}$ lines long, but little exserted; sepals oblong and nearly equal, silky within and without. — S. Utah; a very peculiar species.

* * * * * * Annuals, di- or trichotomously divided, with mostly conspicuous leafy bracts: involucres turbinate, unequally 4–8-lobed or parted (lobes erect), long-pedunculate or sometimes sessile in the forks: flowers not attenuate at base: akenes glabrous. — (§ FOLIOSA, Benth., Torr. & Gray.)

+ Involucres rather large, deeply cleft: flowers glabrous; sepals broad and cordate at base.

28. E. ABERTIANUM, Torr. Stout and leafy, often tall, silky-villous: leaves ovate or subcordate, the bracts becoming oblanceolate or linear: flowers rose-colored, the outer sepals round-cordate, at length 2 lines broad, the inner linear-oblong. — E. Arizona and New Mexico.

29. E. PHARNACEOIDES, Torr. Tall and slender, loosely branched tomentose and villous: leaves linear-oblanceolate, revolute: flowers whitish, a line long; outer sepals ovate, at length bigibbous at base, the inner linear-oblong, retuse. — Arizona and New Mexico.

+ + Involucres divided: flowers pubescent, yellow; sepals narrow, closely appressed to the akene.

30. E. SALSUGINOSUM, Hook. Low and leafy, glabrous, somewhat fleshy: leaves spatulate-oblanceolate, the bracts becoming linear: akene acutely triangular, a line long. — W. Wyoming to S. Utah and S. W. Colorado.

+ + + Involucres very small, 4-cleft or -parted, few-flowered: flowers pubescent, minute, narrow at base: diffusely branched and very slender, glandular: bracts mostly very small.

31. E. SPERGULINUM, Gray. Leaves and bracts linear-oblanceolate, hirsute: involucres 1–2-flowered: flowers nearly a line long, slightly puberulent. — In the Sierra Nevada.

32. E. HIRTIFLORUM, Gray in herb. Somewhat glandular-puberulent, 6 inches high or less: bracts oblong, hispid: involucres half a line long or less, on erect or nodding pedicels 1 to 3 lines long, or sessile in the forks, 3–5-flowered: flowers very hirsute, reddish, half a line long or less: akenes slightly exserted. — Collected by Dr. Gray, 1872, probably in the mountains of California.

§ 2. Involucres campanulate or short-turbinate, not angled or nerved, with 5 rounded erect teeth, pedunculate in diffuse repeatedly di- or trichotomous panicles: bracts not foliaceous, all ternate, small and mostly triangular and rigid: flowers not attenuate at base: ovary glabrous. Mostly annuals. — GANYSMA.

* Annuals: leaves all radical or nearly so, and mostly rounded: involucres, flowers and akenes small (a line long or less). — (§ PEDUNCULATA, Benth., Torr. & Gray, excl. sp.)

+ Flowers glabrous; outer sepals broad and somewhat cordate at base, the inner much smaller: pedicels very short, deflexed: leaves floccose-tomentose.

33. E. BRACHYPODUM, Torr. & Gray. Low, depressed, rather rigid, much branched and glandular: involucres campanulate-turbinate, $\frac{1}{2}$ to $\frac{2}{3}$ line long, on pedicels less than a line long. — S. E. California.

34. E. PARRYI, Gray in Proc. Am. Acad. x. 77. Less rigidly branched: involucres rather narrowly turbinate, a line long: pedicels slender, 1 to 3 lines long. — S. Utah.

35. E. DEFLEXUM, Torr. Taller and more erect, glabrous above the base: involucres and pedicels as in *E. brachypodum*, but more secund along the branches; pedicels reflexed, rarely a line long or more: outer sepals becoming a line long, the inner very small, obovate and retuse. — Nevada and Utah to S. E. California.

+ + Flowers glabrous; outer sepals panduriform or oblong and emarginate or retuse, the inner narrower: pedicels longer: leaves floccose-tomentose.

++ Pedicels deflexed: outer sepals oblong or somewhat broader above.

36. E. NUTANS, Torr. & Gray. Low, sparingly branched: leaves small: pedicels minutely glandular: involucres campanulate: outer sepals nearly obcordate. — N. E. California and N. Nevada.

37. E. WATSONI, Torr. & Gray. Taller, more diffuse, glabrous: leaves larger, obtuse, round, often cordate at base: involucres narrowly turbinate: outer sepals oblong, often retuse. — N. Nevada.

38. E. CERNUUM, Nutt. Like the last, but leaves broadly ovate, acute: involucres turbinate-campanulate: flowers narrower at base, the outer sepals broader above, retuse. — E. Oregon to Colorado and New Mexico.

++ ++ Pedicels erect or somewhat spreading: outer sepals much broader above.

39. E. THURBERI, Torr. Very slender, tomentose below: leaves small: pedicels a half to an inch long: involucres often glandular-puberulent: flowers becoming a line long; outer sepals with a large rounded terminal lobe, minutely pubescent in the centre. — S. California and Arizona.

40. E. ROTUNDIFOLIUM, Benth. Rather stouter and more diffuse, with larger leaves: pedicels shorter and more rigid: flowers becoming 1½ lines long, the outer sepals very broadly dilated above. — New Mexico and W. Texas.

+ + + Flowers mostly minutely glandular-hispid, longer than the small involucre, the outer sepals mostly ovate: pedicels long and filiform, rarely deflexed.

++ Leaves floccose-tomentose: stem not inflated: pedicels all in the forks or terminating the branches.

41. E. PUSILLUM, Torr. & Gray. Often tall and rather stout: leaves rounded or obovate, usually less tomentose above: greenish bracts and involucres minutely glandular-hispid: involucres hemispherical: flowers yellow, often reddish: akene thick-lenticular. — N. W. Nevada to Arizona and S. California.

42. E. RENIFORME, Torr. Low and slender, glabrous: leaves reniform or cordate-orbicular, densely white-tomentose both sides: bracts smooth, the margins ciliate: involucres smooth, turbinate-campanulate, nearly a line long: flowers rose-colored, glabrous; sepals ovate-oblong. — S. California.

43. E. SUBRENIFORME. Sparingly villous at the nodes: leaves round-reniform or -cordate, tomentose beneath, silky-villous above: involucres smooth, turbinate-campanulate, ½ line long: flowers rose-colored, glabrous, or slightly hispid; sepals oblong. — *E. reniforme*, Torr. & Gray, Rev. 184, in part. Arizona, S. Utah.

44. E. THOMASII, Torr. Low, very slender, glabrous: leaves rounded and ovate, small: bracts minute, glabrous: involucres turbinate-campanulate, smooth: flowers yellowish, often reddish, slightly hispid or glabrous; outer sepals often much dilated below, the inner linear-oblong. — S. California to S. W. Colorado.

++ ++ Leaves more or less villous-pubescent or glabrous, not tomentose: stem often inflated: pedicels often scattered and secund on the branches.

45. E. TRICHOPODUM, Torr. Glabrous, diffusely much branched and very slender, the stem rarely inflated: leaves pubescent: bracts very small: involucres minute: pedicels 3 to 6 lines long: flowers yellow-

ish, pubescent, ½ line long; sepals ovate-lanceolate, acute. — S. California to New Mexico.

46. E. INFLATUM, Torr. Taller, less branched, the stem and internodes longer and often inflated: pedicels 6 to 12 lines long: flowers and akene twice larger. — S. California to Nevada and Arizona.

47. E. GORDONI, Benth. A similar species, but glabrous throughout, or the petioles slightly pubescent: flowers glabrous, light rose-color: outer sepals ovate, the inner oblong. — Colorado.

48. E. GLANDULOSUM, Nutt. Beset with short-stipitate glands: leaves small, obovate, somewhat villous: involucres glabrous, half a line long, turbinate-campanulate: flowers nearly a line long, slightly hispid; sepals oblong-ovate, acutish. — Collected only by Dr. Gambel, probably in New Mexico.

49. E. SCALARE. A peculiar allied species, collected in imperfect specimens by Dr. T. H. Streets, U.S.N., at Canvas Point, on the coast of Lower California. Main branches of the inflorescence slender and glabrous, a foot long, with opposite or alternate branchlets (sometimes in threes), divaricate or ascending: bracts distinct, linear, a line or two long, spreading or reflexed, on the branchlets smaller and erect: pedicels scattered on the branchlets, 1 or 2 lines long, filiform, ascending: involucres narrowly turbinate, ⅔ line long, glabrous: bracteoles spatulate, naked: flowers slightly pubescent, a line long; sepals oblong, the inner a little narrower.

* * Perennial or biennial, the peduncles and inflorescence glabrous and leafless: involucres and flowers larger, glabrous: akene 2 or 3 lines long. — (Spec. of §§ PEDUNCULATA & ALATA, Benth., Torr. & Gray.)

+- Perennial; woody caudex much branched and leafy: densely white-tomentose.

50. E. TENELLUM, Torr. Tall; branches of the caudex short and crowded or elongated: leaves ovate or rounded, tomentose both sides: inflorescence rather sparingly branched: flowers white or pinkish, becoming 1½ lines long; outer sepals broadly obovate or orbicular, the inner linear-oblong. — S. Colorado to W. Texas and New Mexico.

+- +- Biennial (?); peduncle very sparingly branched: leaves all radical, villous.

51. E. CILIATUM, Torr. Leaves broadly spatulate, 2 inches long, glabrous excepting the very villous margin and midrib: involucres few, long-pedunculate: flowers deep red; sepals ovate, acute, the inner narrower. — Northern Mexico.

52. E. ATRORUBENS, Engelm. Very similar: leaves narrowly lanceolate, 4 inches long, on long petioles, villous, somewhat tomentose beneath: peduncle inflated: flowers deep red: akene somewhat winged above with a thick narrow margin. — Chihuahua.

* * * Annuals (or n. 54 perennial), branching from the base, with leaves developed at the nodes in the axils of ordinary triangular bracts: flowers minutely glandular. — (§ SUBSTIPULATA, Benth. PSEUDO-STIPULATA, Torr. & Gray.)

53. E. ANGULOSUM, Benth. Floccose-tomentose, the branches mostly 4-6 angled: lower leaves orbicular to oblong-ovate, the upper oblong to oblanceolate: involucres hemispherical, very many-flowered: flowers rose-colored or greenish, ½ line long; outer sepals ovate, concave, the inner longer, lanceolate. — California to Arizona and Utah.

54. E. GREGGII, Torr. & Gray. Apparently perennial, puberulent: leaves spatulate, ciliate and somewhat villous, smooth above, acutish: involucres turbinate-campanulate, many-flowered: flowers purplish, the sepals ovate-oblong. — N. Leon, Mexico.

55. E. DIVARICATUM, Nutt. Low, greyish pubescent: branches terete: leaves thickish, all rounded or the upper oblong, petiolulate: involucres very small and few-flowered: flowers whitish; sepals oblong, nearly equal. — W. Wyoming and S. W. Colorado.

* * * * Tall stout white-tomentose annuals, with leafy simple stems, naked above: inflorescence cymose: involucres turbinate-campanulate, shortly pedunculate: flowers white, nearly glabrous; sepals very unequal, the outer ovate-oblong or round-cordate. — (Sp. of § CORYMBOSA, Benth., Torr. & Gray.)

56. E. ANNUUM, Nutt. Leaves narrowly oblanceolate or oblong, attenuate to a short petiole, mostly flat: involucres densely white-tomentose: flowers ½ to 1 line long; outer sepals oblong-obovate. — Colorado to W. Texas and Northern Mexico.

57. E. MULTIFLORUM, Benth. Leaves lanceolate, sessile and somewhat auricled at base, smoother above and margin undulate: involucres smoother: flowers 1½ lines long; outer sepals rounded cordate. — Arkansas, Louisiana, and Texas.

§ 3. Involucres cylindric-turbinate, more or less strongly 5–6-nerved, and often becoming costate or angled, with as many short erect teeth, sessile (rarely some of them pedunculate) in heads or clusters, or scattered in cymes or along virgate panicled branches, always erect, rather large (1 to 3 lines long): bracts ternate, connate at base, usually short, acute and more or less rigid (sometimes more or less foliaceous): flowers not attenuate at base: akenes usually glabrous. Mostly perennials, sometimes woody and leafy, more or less white-tomentose. — OREGONIUM.

* Outer sepals broad and somewhat cordate, the inner much narrower: cespitose densely tomentose perennials, with short closely branched caudex: involucres in a single head or short cymose umbel on the naked peduncle: ovary scabrous above. — (§ HETEROSEPALA, Torr. & Gray, & sp. of § VIRGATA, Benth., Torr. & Gray.)

58. E. OVALIFOLIUM, Nutt. Low, densely cespitose: leaves round or rarely oblong: bracts very small: involucres in a single close head:

flowers rose-colored, white, or yellow; outer sepals oblong, becoming orbicular, the inner spatulate, often retuse. — Var. PROLIFERUM. Involucres more or less cymose-umbellate. *E. proliferum*, Torr. & Gray. — N. California to Colorado and British America; frequent.

59. E. DICHOTOMUM, Dougl. Caudex more diffuse: leaves oblanceolate, acute: lower bracts often foliaceous: inflorescence cymose-umbellate; the involucres mostly solitary, about three lines long, strongly toothed: flowers white or pinkish; outer sepals broadly elliptical, the inner linear-spatulate. — *E. Greenei*, Gray, Proc. Am. Acad. xii. 83. Oregon and N. California.

60. E. NIVEUM, Dougl. Like the last: most of the bracts more or less foliaceous and spreading: involucres usually shorter and broader, with some or all of the teeth produced and often recurved: outer sepals round-oval, the inner obovate-spatulate. — Including *E. strictum*, var. *lachnostegia*, Benth., referred to the last in Torr. & Gray, Rev. 175. Washington Terr. to Oregon and Idaho.

* * Flowers narrower at base, the sepals similar and nearly equal: akenes smooth or nearly so.

+ Perennials with short-branched caudex, naked peduncles, small bracts, and capitate involucres (rarely solitary).

++ Heads solitary (few and umbelled in n. 66): dwarf and cespitose, alpine or subalpine, densely white-tomentose. — (§ CAPITATA, Torr. & Gray, excl. sp.)

61. E. KENNEDYI, Porter, MS. Dwarf and very densely matted: leaves narrowly oblong, revolute, 1½ to 3 lines long, densely tomentose both sides: peduncles very slender and wiry, glabrous, 2 to 4 inches high: involucres 2 to 10, somewhat tomentose, thick and strongly nerved, with short teeth, 1½ lines long: flowers glabrous, white, veined with red, 1½ lines long. — In the Sierra Nevada, Kern Co., California; W. L. Kennedy, 1876.

62. E. KINGII, Torr. & Gray, excl. var. Dwarf and densely cespitose, villous-tomentose throughout: leaves oblanceolate or spatulate, an inch long or less, including the slender petiole: involucres thin and scarious, deeply toothed, villous, in dense heads: flowers rose-colored, glabrous. — N. Nevada.

63. E. PAUCIFLORUM, Nutt. Rather less densely cespitose, tomentose throughout, or the linear-oblanceolate revolute leaves (2 inches long) glabrous above: involucres broadly turbinate, nearly glabrous, 2 lines long, thin, with broad somewhat scarious teeth: flowers white, glabrous. — Colorado.

64. E. CHRYSOCEPHALUM, Gray, Proc. Am. Acad. xi. 101. Caudex more diffusely branched, woody: tomentose throughout, the narrowly

oblanceolate leaves (1 to 2 inches long) sometimes glabrate above: involucres narrower and rather more firm, 1½ lines long, shortly toothed, somewhat tomentose: flowers yellow, glabrous. — *E. Kingii*, var. *laxifolium*, Torr. & Gray, Rev. 165. Wahsatch Mountains.

65. E. MULTICEPS, Nees. Densely white-tomentose throughout, rather diffusely branched at base: leaves narrowly oblanceolate, 1 or 2 inches long: peduncles 2 to 6 inches high: involucres rigid, narrowly turbinate, 1½ to 2 lines long, with very short teeth; one of the bracts often foliaceous: flowers rose-colored, pubescent, a line long. — Nebraska and Colorado.

66. E. SPATHULATUM. Gray, Proc. Am. Acad. x. 76. Tomentose throughout, somewhat diffuse at base, the stout peduncles (8 inches high) usually bearing a simple few-rayed umbel: leaves linear-oblanceolate, 2 to 4 inches long: involucres rather broadly turbinate and rigid, 2 lines long, with broad acute teeth: flowers white, glabrous, 2 lines long. — S. Utah.

+ + Peduncles mostly tall and stout, from a sparingly branched caudex: heads solitary or few, in a long-jointed subumbellate cyme: flowers white or rose-colored. — (§ CAPITELLATA, Torr. & Gray, and § CAPITATA, in part.)

67. E. LATIFOLIUM, Smith. Stout, tomentose throughout: peduncle not fistulous: leaves oblong to ovate: involucres tomentose, 2 lines long, in large dense heads (solitary, or few in a nearly simple umbel): flowers glabrous. — *E. oblongifolium*, Benth.; Torr. & Gray, Rev. 167. Seashore, California.

68. E. NUDUM, Dougl. More slender, mostly glabrous above: peduncle fistulous or inflated: leaves broadly ovate to oblong, cordate or abruptly cuneate at base, glabrate above: involucres glabrous or nearly so, 2 or 3 lines long, in smaller and more numerous heads in a sparingly branched panicle: flowers glabrous or somewhat villous. — Var. PAUCIFLORUM. Involucres solitary or occasionally in pairs, much scattered. — Var. OBLONGIFOLIUM. Often somewhat tomentose throughout: leaves oblong, narrowed to a long slender petiole: bracts occasionally foliaceous: flowers usually somewhat pubescent. *E. affine*, Benth. — Washington Territory to S. California.

69. E. ELATUM, Dougl. Leaves large, villous-pubescent, ovate-oblong to lanceolate: peduncle (fistulous or inflated) and rigid panicle 1½ to 3 feet high, smooth and glaucous: involucres glabrous, in clusters of 2 to 5: flowers somewhat villous. — Washington Territory to N. California and W. Nevada.

+ + Stout woody perennials, more or less tomentose, virgately branched and very leafy: leaves small (9 lines long or less), shortly petioled and often

fascicled: bracts mostly foliaceous: involucres capitate or fascicled, the clusters more or less closely cymose-umbellate. — (§ FASCICULATA, Benth., Torr. & Gray.)

70. E. CINEREUM, Benth. Leaves round to oblong, obtuse: peduncles elongated, sparingly dichotomous, with few rather open heads: bracts short: flowers very villous. — Seacoast, S. California.

71. E. PARVIFOLIUM, Smith. Leaves broadly ovate to oblong, acute: peduncles usually rather short, with few close heads: lower bracts conspicuous: flowers glabrous. — Near the coast, S. California.

72. E. FASCICULATUM, Benth. Leaves narrowly oblanceolate, acute, usually revolute, often glabrate above, much fascicled: peduncles short or elongated, bearing a short cymosely divided umbel, often much contracted or capitate: bracts more or less conspicuous: involucres pubescent or glabrate: flowers glabrous or often villous. — *E. ericæfolium*, Torr. & Gray, Rev. 170. S. California to Arizona and S. Utah. Very variable.

+ + + Involucres mostly solitary (terminal and alar), in a repeatedly di- or trichotomous corymb-like cyme: leaves not fascicled: bracts small, very rarely foliaceous below. — (§ CORYMBOSA, Benth., Torr. & Gray, excl. sp.)

++ Perennials, woody and diffusely much-branched, leafy below: leaves ovate- to oblong-oblanceolate or linear: sepals obovate, the inner emarginate.

73. E. MICROTHECUM, Nutt. Low and rather slender, more or less white-tomentose: leaves usually narrow, revolute, becoming glabrate above: involucres usually small ($\frac{3}{4}$ to $1\frac{1}{2}$ lines long), often pedunculate: flowers a half to a line long. — Var. EFFUSUM, Torr. & Gray. With very diffuse and repeatedly divided inflorescence. — Oregon and eastern base of Sierra Nevada to Nebraska and New Mexico; the variety eastward.

74. E. CORYMBOSUM, Benth. Stouter and more rigid, usually densely tomentose: leaves broader and less revolute: umbel stiff, broadly cymose: involucres mostly sessile, 1 to 2 lines long: flowers a line or two long. — Including *E. microthecum*, var. *Fendlerianum*, Benth., Torr. & Gray. Of nearly the same range and hardly distinct.

++ ++ Perennials, less woody and more shortly branched at base: leaves mostly narrow: sepals nearly equal.

75. E. THOMPSONÆ, Watson in Am. Naturalist, vii. 302. Stout and rigid, erect, a foot high, yellowish, glabrous above the tomentose base: leaves obovate-oblong, densely tomentose beneath, glabrate above, on long petioles: involucres 2 lines long: flowers yellow, $1\frac{1}{2}$ lines long. — S. Utah.

76. E. BREVICAULE, Nutt. More lax and slender, glabrous or glabrate above the white-tomentose base: leaves linear to narrowly oblanceolate, 1 to 3 inches long, attenuate to a very short petiole, often revolute, sometimes glabrate above: involucres 1½ lines long, nearly glabrous: flowers yellow, a line long. — Idaho and Wyoming to New Mexico.

77. E. LONCHOPHYLLUM, Torr. & Gray. Described as taller than the last (a foot high or more), with a loose panicle-like cyme; leaves lanceolate to broadly linear, 3 inches long and attenuate into a petiole an inch long or more: flowers white, few in the involucres. — New Mexico, only by Dr. Newberry.

← ← ← Annuals: leaves mostly rosulate at the base, a whorl rarely subtending the umbel: peduncle short.

78. E. TRUNCATUM, Torr. & Gray. Slender, a foot high or less, floccose-woolly throughout: leaves oblanceolate, an inch long: umbel leafly-bracted, of 4 to 6 elongated once or twice divided rays: involucres tomentose, oblong-turbinate, 2 lines long: flowers rose-colored, a line long. — Near Mount Diablo, California; W. H. Brewer.

79. E. MOHAVENSE. Very slender, glabrous except at the base: leaves round or ovate, tomentose, small: umbel naked, of 3 or more repeatedly divided rays: involucres glabrous, broadly turbinate, a line long: flowers yellow, very small (scarcely a half line long), abruptly narrowed at base. — Mohave Valley; Dr. Edward Palmer, 1876.

80. E. LEMMONI. Rather stout, a span high, more or less hirsute with very short spreading hairs, not at all tomentose: leaves orbicular-reniform, 6 to 9 lines broad, on slender petioles: peduncle fistulous or inflated, bearing a naked 3-rayed narrow umbel, twice or thrice divided: involucres glandular-pubescent, rather broadly turbinate, 1½ lines long: flowers pale rose-color, half a line long, with narrow sepals. — On sand hills near Reno, Nevada; J. G. Lemmon, 1876. A very peculiar species.

← ← ← ← Involucres sessile and solitary (often secund) along the ascending and usually long-virgate branches of the open naked dichotomous panicle: lowest bracts rarely foliaceous: flowers glabrous (except in n. 89). — (§ VIRGATA, Benth., Torr. & Gray, excl. sp.)

← White-tomentose perennials, leafy below: panicle sparingly branched, usually virgate: involucres tomentose, the teeth not margined: flowers white or rose-colored.

81. E. WRIGHTII, Torr. Much branched and usually very leafy at base, rather slender: leaves oblong- to linear-oblanceolate, acute, an inch long or less: bracts all small, triangular: involucres and flowers

1 to 1½ lines long: akene scabrous above, very acute at base. — California to New Mexico. Variable; inflorescence in subalpine specimens at times reduced to a very few nearly capitate involucres.

82. E. SAXATILE. Biennial or perennial (?), sparingly branched and very leafy at base, rather stout, a foot high or less: leaves rounded or obovate, obtuse, 6 to 8 lines broad or less, cuneate at base upon a short thick petiole, densely tomentose both sides: branches of the cymose panicle short and somewhat spreading: bracts larger, subfoliaceous, triangular to acute-oblong: involucres and flowers 1½ to 2 lines long: sepals appressed to the nearly glabrous akene, which is more abruptly narrowed at base. — On rocks above San Bernardino (Dr. C. C. Parry, 1876), and in the Santa Lucia Mountains, Dr. E. Palmer.

83. E. STRICTUM, Benth. Very slender, glabrate above: branches of caudex very short: leaves small, ovate to oblanceolate, on long slender petioles: panicle twice or thrice divided, with 1 to 3 involucres on the short branches: bracts short, the lower somewhat elongated: flowers and glabrate involucres 1½ lines long. — Blue Mountains, Oregon.

84. E. RACEMOSUM, Nutt. Sparingly or not at all branched at base, stout, 1 to 3 feet high: leaves large (1 to 2½ inches long), ovate or oblong, on long petioles: lower bracts somewhat foliaceous: involucres approximate upon the few strict branches of the once or twice forked panicle: flowers 2 lines long. — Utah to New Mexico.

85. E. ELONGATUM, Benth. Sparingly branched at base, a foot or two high: leaves usually scattered, smaller, lanceolate to ovate, on short petioles: bracts rarely elongated: involucres 2½ to 3 lines long, obtusely toothed, distant on the few elongated branches of the panicle. — S. California, near the coast.

++ ++ Perennials, woody and leafy below: panicle diffuse with short and rigid branchlets: involucres short, with rounded and more or less membranously margined teeth; bracts very small.

86. E. HEERMANNI; Dur. & Hilg. A foot high, soon glabrate above, divaricately dichotomous, the branchlets somewhat spinescent: leaves oblanceolate, ½ inch long, on slender petioles: involucres few and distant, campanulate, a line long: flowers rose-colored or yellowish, 1½ lines long. — S. California, Nevada.

87. E. PALMERI. More tomentose throughout, and usually taller: leaves oblanceolate, ½ inch long, on short petioles: branches somewhat flexuous, mostly alternately divided, the short branchlets divaricate or deflexed, very short-jointed: involucres rather numerous, narrowly turbinate, a line long, nearly glabrous: flowers a line long, reddish white;

outer sepals cuneate-obovate, the inner slightly narrow: akene somewhat pubescent, — San Diego County, California, and in S. Utah; Dr. Edward Palmer.

+ + + Annuals: leaves usually rosulate at the base, and occasionally occurring at the nodes.

= Tomentose throughout: branches of the panicle virgate, sparingly divided: involucres narrow, 2 lines long.

88. E. VIRGATUM. Benth. A foot or two high: leaves oblanceolate: branches elongated, ascending: flowers glabrous, a line long, white, reddish, or yellow. — California; variable, verging upon *E. vimineum*.

89. E. DASYANTHEMUM, Torr. & Gray. Shorter, more slender: leaves rounded, somewhat scattered: panicle more branched, rather diffuse: involucres very narrow: flowers a line long or less, somewhat villous. — N. California.

= = More slender and diffuse, glabrous or somewhat tomentose: involucres smaller, narrow or turbinate.

90. E. VIMINEUM, Dougl. Rather diffuse, the branches often elongated, usually somewhat tomentose, at least below the panicle: leaves rounded to broadly ovate: involucres $1\frac{1}{2}$ lines long, narrow and often contracted above: flowers rose-colored, or yellowish, a line long or more. — Washington Territory to N. Nevada and S. California; variable.

91. E. BAILEYI, Watson, Proc. Am. Acad. x. 348. Very diffusely much-branched, glaucous and glabrous: leaves round to broadly ovate, densely tomentose: involucres a line long or usually less, mostly wider above with obtuse teeth: flowers $\frac{1}{2}$ to $\frac{3}{4}$ line long. — Var. TOMENTOSUM. Loosely tomentose throughout: bracts more linear: involucres broadly turbinate, deeply toothed. — N. W. Nevada to S. California and Arizona.

92. E. GRACILE, Benth. Usually more strict and narrowly panicled, more or less tomentose throughout: leaves oblanceolate or oblong: bracts more or less elongated or foliaceous, the lower often including one or more leaves: involucres a line long or less, broader above, with rigid acute teeth: flowers $\frac{3}{4}$ line long. — S. California; very variable.

93. E. POLYCLADON, Benth. Stouter, white-tomentose throughout, the stem leafy its whole length: panicle erect and elongated: leaves oblong-lanceolate: sepals narrower at base and bracteoles much more villous. — Arizona and New Mexico.

94. E. Plumatella, Dur. & Hilg. Low, grayish tomentose throughout: intricately much-branched from the base, leaves rounded: involucres ½ line long or less: flowers ¾ to at length 1½ lines long, the sepals broadly cuneate-obovate and retuse. — N. W. Nevada to S. California.

95. E. intricatum, Benth. Leaves rounded and viscid-pubescent: panicle diffuse with numerous short divaricate branchlets, glabrous or glabrate: involucres very small, glabrous: flowers minute, sparingly pubescent. — Lower California.

CHORIZANTHE, R. Br. A polymorphous genus, with which it seems necessary to unite *Centrostegia* as too closely related to the section *Mucronea* to be kept distinct. The character upon which that genus mainly rested, the spurs at the base of the involucre, is of frequent occurrence in the Chilian Chorizanthe *commissuralis*, which is without doubt a true *Chorizanthe*. Moreover, the involucres and spurs in the two recognized species of *Centrostegia* are very different in character, and in some of the *Mucronea* species the angles of the involucres are frequently rather strongly gibbous at base, showing a tendency towards a like peculiarity. The known species, excepting the perennials of Chili, are the following: —

§ 1. Glabrous or glandular, not villous or tomentose, with radical spatulate leaves and ternate foliaceous more or less connate bracts: involucres in open dichotomous panicles, coriaceo-chartaceous, the awns not uncinate: flowers 6-parted, soft-pubescent, on slender pedicels: stamens 9, inserted at the base. — Mucronea. S. California.

* Involucres 1–3-flowered, with 3 to 6 mostly erect teeth and 3 to 6 divaricate cuspidate or awned spurs at base: bracts small. — (*Centrostegia*, Gray.)

1. C. Thurberi. Involucres chartaceous and triangular, with 3 to 5 broad short teeth, and 3 broad straight spurs. — *Centrostegia Thurberi*, Gray.

2. C. leptoceras. Involucres coriaceous, deeply 4-6-cleft, the lobes rigid and attenuate, and with as many rigid usually uncinate awn-like spurs. — *Centrostegia leptoceras*, Gray.

* * Involucres 1-flowered, with 2 to 5 stout divergent teeth, not spurred: bracts conspicuous. — (*Mucronea*, Benth. § *Mucronea*, Torr. & Gray.)

3. C. perfoliata, Gray. Sparingly glandular-hirsute: bracts perfoliate: involucres scattered: sepals laciniate.

4. C. Californica, Gray. More hirsute: bracts unilateral: involucres often clustered: sepals entire.

§ 2. Villous-pubescent or hirsute, not glandular, fragile: bracts 1 to 3, distinct, at least the uppermost acicular-subulate: involucres more or less clustered or capitate, coriaceous, 1-flowered, 6-angled and toothed, the divergent teeth often uncinate: flowers mostly 6-cleft, nearly sessile, glabrous or bristly-villous on the midveins (pubescent in n. 5): stamens mostly 9, inserted below the middle. — EUCHORIZANTHE, Torr. & Gray.

* Involucres subcapitate; margins of the teeth mostly scarious: stems more or less leafy and bracts foliaceous.

+ Teeth united by a petaloid margin (except in the alar involucres): stems erect: heads few and dense.

5. C. MEMBRANACEA, Benth. Floccose-tomentose, slender, leafy: leaves linear: scarious limb of the involucre at length broadly dilated: flowers as in the preceding section; the sepals spatulate: stamens at the base. — Mendocino County to San Luis Obispo.

6. C. STELLULATA, Benth. Low, hirsute: leaves linear-oblanceolate, scattered: involucres 2 or 3 lines long; margin of the teeth narrower: flowers glabrous, sessile, 2½ lines long, equally 6-cleft; segments obcordate. — Sacramento Valley; only from Hartweg.

7. C. DOUGLASII, Benth. Similar, but leaves in 1 or 2 whorls: involucres 1½ lines long: flowers shortly pedicelled, a line long; segments truncate, the outer cuspidate, the inner shorter and retuse. — Near Monterey (?); only from Douglas.

+ + Teeth distinct, scariously margined or herbaceous: usually more diffuse and decumbent, villous-pubescent, with more numerous scattered heads.

++ Slender and mostly decumbent: involucres and flowers 1 to 1½ lines long.

8. C. DIFFUSA, Benth. Leaves narrowly spatulate, an inch long or less: bracts short, acerose: involucres and flowers a line long, the teeth long-awned and broadly scarious: calyx-segments oblong, nearly equal, the inner slightly narrower. — Near Monterey.

9. C. BREWERI. Ascending or erect, 2 to 4 inches high, softly pubescent: leaves ovate or rounded, 3 to 6 lines broad, on slender petioles: bracts foliaceous, linear-oblanceolate, pungent: involucres and flowers 1½ lines long, the short slightly unequal teeth united at base by an inconspicuous margin, stout and curved, shortly awned: flowers glabrous or villous; segments broadly oblong, the inner ones shorter: stamens at the base. — On dry rocky hillsides at San Luis Obispo and in San Margarita Valley; collected by Prof. W. H. Brewer.

10. C. PUNGENS, Benth. Decumbent or at first erect: leaves oblanceolate, mostly opposite: bracts foliaceous: involucres 1½ to 2 lines long, the unequal teeth usually margined: calyx-segments short, equal, oblong. — San Francisco and southward, common.

++ ++ Stouter, erect: bracts foliaceous: involucres and flowers 2 to 2½ lines long.

11. C. VALIDA. Mostly stout, 6 inches high or less, sparingly branched: leaves oblanceolate, an inch long, the bracts similar: involucres in rather close heads, 2½ to 3 lines long; teeth nearly equal, slightly spreading with straight awns, scarcely margined: flowers 2½ lines long, villous or glabrous; segments oblong, very unequal, the shorter ones erose: stamens adnate to the middle of the tube or nearly to the top. — Specimens in herb. Gray are from the "Russian Colony" (from herb. Acad. St. Petersb.), and also collected by Rev. Mr. Samuels, probably in the same region.

12. C. PALMERI. Stout and branching, a span high or less: leaves spatulate, 2 inches long: bracts oblanceolate, conspicuous: involucres in large close cymes, 2 lines long; teeth not margined, slightly divergent, one long-awned, the rest nearly equal: flowers glabrous, broadly lobed; outer segments rounded, entire, the inner shorter, truncate or bifid, shortly laciniate: stamens near the base. — Near San Luis Obispo; Dr. Edward Palmer, 1876 (n. 464).

* * Involucres at length scattered or only loosely cymosely clustered; teeth unequal, not margined.

+ Calyx-segments lanceolate, fimbriate: leaves all radical: bracts not foliaceous: villous-pubescent or glabrate. — S. California.

13. C. FIMBRIATA, Nutt. Segments coarsely fringed below the obtuse summit.

14. C. LACINIATA, Torr. Segments long-acuminate, copiously fringed.

+ + Calyx-segments short, oblong, entire.

++ Bracts not foliaceous.

15. C. STATICOIDES, Benth. Erect, often a foot high, branching above: leaves oblong, tomentose beneath: involucres 1½ to 3 lines long, alternate teeth often much enlarged: flowers rose-colored, 2 to 2½ lines long, glabrous; segments oblong, the inner ones nearly a half shorter. — Monterey to San Diego.

16. C. PROCUMBENS, Nutt. Slender, procumbent, diffusely branched from the base: leaves spatulate, not tomentose: involucres 1 to 1½ lines long: flowers yellowish, 1½ lines long, with equal narrowly oblong segments. — San Diego.

++ ++ Bracts more or less foliaceous: flowers 1½ lines long: branched from the base.

17. C. PARRYI. Small, villous-pubescent, leafy: leaves narrowly

oblanceolate, not tomentose, an inch long: lower bracts as large, similar: tube of involucre a line long, the very divergent alternate teeth as long or longer: flowers white or pinkish, villous; segments recurved, somewhat undulate, oblong-ovate, crenate, acutish, the inner narrower, scarcely shorter: stamens 9. — Common on gravelly mesas near Crofton, San Bernardino County; Dr. C. C. Parry, 1876.

18. C. Xanti. Small, villous-pubescent and tomentose: the leaves ovate-oblong, 2 to 6 lines long, tomentose beneath: lower bracts similar or linear-oblanceolate: involucres tomentose, in diffuse cymes, the tube 2 lines long; teeth very divergent, often half as long or more, the alternate ones much smaller: flowers rose-colored, 2½ lines long, villous; segments linear-oblong, entire, acutish, the inner a half shorter: stamens 6 (rarely 7 or 8.) — *C. procumbens*, Gray, Proc. Bost. Soc. vii. 148; referred to *C. staticoides*, in Torr. & Gray, Rev. 195. Near Fort Tejon (C. L. Xantus, Dr. Horn); San Bernardino and San Gorgonio, on sandy washes, Dr. C. C. Parry.

19. C. Wheeleri. Small, villous-pubescent and tomentose: leaves and bracts tomentose beneath, the latter oblanceolate, an inch long or less: involucres in small cymes, nearly glabrous, a line long, with short stout teeth, the alternate ones smaller: flowers rose-colored, 1½ lines long, glabrous; segments broadly oblong, the inner slightly shorter and broader: stamens 6. — Near Santa Barbara; Dr. J. T. Rothrock, on Lieut. G. M. Wheeler's Geogr. Survey, 1876.

20. C. uniaristata, Torr. & Gray. Villous-pubescent: leaves and bracts spatulate or oblanceolate: involucres numerous, scattered; one tooth with a long straight awn, the rest short and uncinate: flowers yellowish, 1½ lines long; segments very unequal, the outer obovate, entire, the inner oblong, crenate: stamens 3 or 9. — S. California; near New Idria (Prof. Brewer), and on the Upper Salinas, Dr. Palmer.

21. C. brevicornu, Torr. Pulverulent or nearly glabrous, erect or ascending, very fragile at the tumid nodes: leaves and bracts broadly spatulate to linear-oblanceolate: involucres scattered, narrow; teeth very short, uncinate: flowers included; segments narrowly oblong, nearly equal: stamens 3 or 6. — N. W. Nevada to S. E. California and S. Utah.

§ 3. Villous-pubescent and tomentose, low, branching and fruiting from the base: bracts 2 or 3, distinct: involucres scattered, coriaceous, 1-flowered, unequally 3–5-toothed or -lobed, triangular or cylindrical, transversely corrugated: flowers tubular, shortly and equally 6-cleft, glabrous: stamens 6 or 9, short, on the throat. — Acanthogonum, Torr. & Gray.

* Involucres broadly triangular: bracts foliaceous: flowers nearly sessile.

22. C. POLYGONOIDES, Torr. & Gray. Decumbent, villous-pubescent: leaves and bracts narrowly oblanceolate; floral bracts very short: involucres 3-costate, with 3 stout broad divergent uncinate teeth, exceeding the (1 line tube) long. — Near Placerville, California; only by Rattan.

23. C. RIGIDA, Torr. & Gray. Erect, low, dense, becoming rigid and persistent: leaves and bracts ovate, tomentose beneath; floral bracts linear-subulate, stout and spinescent, 6 to 15 lines long: involucres 6-costate, with 3 very unequal lanceolate carinate spinescent or pungent teeth. — N. W. Nevada to S. E. California and S. Utah.

* * Involucres cylindrical: bracts not foliaceous, subulate-setaceous: flowers on slender pedicels: leaves tomentose beneath: low.

24. C. CORRUGATA, Torr. & Gray. Leaves ovate: the involucres strongly corrugated, 3-toothed: flowers white, included: stamens on the middle of the tube. — Valley of the Lower Colorado.

25. C. WATSONI, Torr. & Gray. Leaves narrowly oblanceolate: bracts rarely foliaceous: the involucres obscurely corrugated, very unequally 5-toothed: flowers yellow, slightly exserted. — N. Nevada to S. E. California.

OXYTHECA INERMIS. Low and slender: leaves broadly oblanceolate, glabrous, with scabrous-ciliate margin: bracts linear-oblong, united only at base, acute without awns, 2 or 3 lines long: involucres shortly pedicelled, 4-parted nearly to the base, the oblong-lanceolate lobes nearly equal, acute without awns, a line long: flowers rose-colored, half a line long; sepals oblong, the inner smaller and retuse. — California, probably on Mount Diablo: collected only by Miss M. J. Bancroft. Remarkable for the total absence of awns, but otherwise with the characters of the genus, and nearly allied to *O. dendroidea*, Nutt.

AMARANTUS (PYXIDIUM) BLITOIDES. Prostrate or decumbent, the slender stems becoming a foot or two long, glabrous or nearly so: leaves broadly spatulate to narrowly oblanceolate, attenuate to a slender petiole, an inch long or usually less: flowers in small contracted axillary spikelets: bracts nearly equal, ovate-oblong, shortly acuminate, 1 to 1½ lines long, little exceeding the oblong obtuse and mucronulate or acute sepals: utricle not rugose, slightly longer than the sepals: seed nearly a line broad. — Frequent in the valleys and plains of the interior, from Mexico to N. Nevada and Iowa, and becoming introduced in some of the Northern States eastward. It somewhat resembles the *A. Blitum*, Linn., of the Old World, and has been mistaken

for it; but that species is usually erect, with shorter and more scarious bracts, and a smaller seed more notched at the hilum. The allied *A. albus*, Linn., also common and indigenous throughout the interior, is distinguished by its usually erect diffusely branched habit: rhachis of the spikelets often somewhat elongated (½ to 3 lines long): bracts subulate, rigid, pungently awned, 1 to 2½ lines long, the lateral ones very much smaller or wanting: sepals oblong-lanceolate, acuminate, shorter than the slightly rugose utricle: seed smaller (⅓ line broad). It is very abundant on the western prairies, where it is popularly known as "rolling" or "tumble-weed," the stem breaking off at the root when dry and the compact top rolling before the wind to any distance.

AMARANTUS (AMBLOGYNE) PALMERI. Diœcious, rather stout, erect, 2 or 3 feet high, branching, somewhat pubescent above or glabrate: leaves oblong-rhomboid, an inch or two long and about equalling the petiole, the upper linear-lanceolate: flowers in close elongated linear spikes, leafy at base: bracts solitary, mostly twice longer than the flowers, spreading, subulate and rigid, narrowed into a stout awn: sepals of fertile flowers distinct or nearly so, 1 to 1½ lines long, oblong and somewhat broader above, obtuse or retuse, two or three usually slightly larger and more acute or setaceously apiculate: stigmas usually 2: utricle circumscissile. — At Larkin's Station, San Diego County, California, by Dr. E. Palmer (n. 323 of his collection); also on the banks of the Rio Grande, by Berlandier (n. 2407) in 1834. Staminate flowers have not been detected among the fruiting specimens, but what is probably to be considered the sterile form has been found by various collectors from the Rio Grande through Arizona to S. California and Cape St. Lucas. These accord in habit and foliage with the pistillate plants, and have very narrowly acuminate or setaceous pungent bracts, equalling or usually exceeding the lanceolate long-acuminate sepals. An examination of all our species of the group seems to fully justify the reference by Mr. Bentham of the genus *Amblogyne* (including *Sarratia*) to *Amarantus*. To the *A. fimbriatus*, *A. Torreyi*, &c., of the same region, the following species from the mouth of the Rio Grande may be added: —

AMARANTUS (AMBLOGYNE) GREGGII. Diœcious, erect, glabrous or nearly so: upper leaves rhombic-ovate, an inch long or less, on short petioles, rather thick and somewhat scabrous: spike elongated, leafy and interrupted at base: bracts solitary, lanceolate, acuminate, scarious, erect, much shorter than the fruiting calyx: sepals distinct, 1½ lines long, oblong-spatulate, acute, the inner ones somewhat the narrower below: stigmas 3: utricle a little shorter, thin and not circumscissile: seed

$\frac{3}{4}$ line broad. — Collected by Dr. Gregg near the mouth of the Rio Grande, in 1848 — only pistillate specimens.

AMARANTUS (EUAMARANTUS) WRIGHTII. Glabrous, erect and slender, with ascending branches and spikes, 2 or 3 feet high or more, reddish: leaves small and thin, the upper ones but an inch long, on slender petioles, oblong to narrowly lanceolate: terminal compound spike erect, narrow, and rather leafy: bracts solitary, subulate, rigid, attenuate into a pungent awn, about $1\frac{1}{2}$ lines long: sepals $\frac{1}{2}$ to nearly 1 line long, oblong to oblong-spatulate, obtuse, sometimes emarginate: utricle about equalling the sepals: seed orbicular, $\frac{1}{2}$ line broad. — Collected at the Copper Mines, New Mexico, by Mr. Wright (n. 1748, in part), October, 1851; also in the Upper Arkansas Valley, by Messrs. Wolf & Rothrock (n. 275) in 1873. Approaching the section *Amblogyne* in the characters of the calyx.

AMARANTUS (EUAMARANTUS) OBOVATUS. Pubescent, slender, erect, 2 feet high, reddish, sparingly branched: leaves small, 1 to $1\frac{1}{2}$ inches long, lanceolate, on short slender petioles: spikes erect, narrow, the terminal ones an inch or two long, the axillary shorter: bracts subulate, acuminate and pungent, $1\frac{1}{2}$ to 2 lines long, much exceeding the unequal narrowly oblong acute sepals: utricle equalling the calyx: seeds oblong-obovate, $\frac{3}{4}$ line long. — Also collected by Mr. Wright and in the same locality, and distributed under the same number; referred in Bot. Mex. Bound. to *A. hybridus.* Remarkable in the shape of the seed.

ATRIPLEX DECUMBENS. Decumbent or procumbent, slender and branching from the base, densely hoary-scurfy, the stems becoming somewhat woody below: leaves mostly opposite, oblong-ovate, sessile, acute or acutish, cuneate or obtuse at base, $\frac{1}{2}$ to 1 inch long or less: staminate flowers in dense clusters in short interrupted terminal spikes; calyx 5-cleft: fruiting bracts coriaceous, compressed, united to above the middle, triangular-cordate, acute, 2 lines long and broad, entire or slightly denticulate, not herbaceously margined nor the sides muricate: seed nearly a line long. — Near San Diego; Dr. E. Palmer, 1876 (n. 334). Allied to *A. leucophylla*, Dietr.

CORALLORHIZA BIGELOVII. Scape stout, 6 to 15 inches high: sepals and petals oblong, obtuse, about 4 lines long, twice longer than the column, purple and veined (not spotted); lateral sepals oblique and with the base of the column strongly gibbous over the top of the ovary; lip entire, fleshy, darker colored and strongly veined, deeply concave, elliptical, broad and somewhat auricled at base, with two thick laminæ; spur none: column rather slender, broadly margined

below: capsule oblong-ovate, 6 to 9 lines long, shortly attenuate to a short pedicel. — *C. striata*, Torrey, Pac. R. Rep. iv. 152, t. 25. In the Sierra Nevada and mountains of N. California. Recognized by Dr. Torrey as distinct from *C. Macræi*, which is doubtless identical with the original *C. striata* of Lindley. The figure cited fails to represent the gibbosity of the perianth. *C. striata* is very similar, but with the flowers still larger (often 6 or 7 lines long); lip rather less fleshy, somewhat narrower below, reflexed above the base, and bearing the prominent laminæ upon the arch: ranging from Washington Territory and Oregon to the Great Lakes.

HABENARIA SPARSIFLORA. Stem rather slender, a foot or two high, leafy: leaves narrowly lanceolate, acutish or acute: bracts linear-lanceolate, acuminate, usually much exceeding the greenish flowers, which are few (10 to 20) and distant: perianth thin and delicate, apparently spreading: sepals 3-nerved, the lateral ones oblong or lanceolate, 2 or 3 lines long, the upper ovate and a little shorter: lip several-nerved, narrow, linear or lanceolate, 3 or 4 lines long, nearly equalling the narrow spur: anther emarginate; stalks of the pollen-masses very slender: glands orbicular: beak of stigma broadly triangular: capsule oblong, sessile, 6 lines long. — *H. Thurberi*, var., Gray, Proc. Am. Acad. vii. 389. Common in the Sierra Nevada and mountains of Northern California; marked by its peculiar habit. The typical *H. Thurberi* is to be referred to *H. leucostachys*.

HABENARIA PEDICELLATA. Stem leafy: raceme loose, 20–30-flowered, with linear-lanceolate bracts shorter than the long-pedicellate flowers: sepals 3-nerved, 2½ lines long, oblong, the upper ovate; lip fleshy, several-nerved, oblong-lanceolate, half broader at base, 3 lines long; spur filiform, twice longer than the sepals: pollen-masses attached to the oblong glands by a short thick pedicel: beak of stigma ovate-triangular, prominent: capsule ovate-oblong, 4 lines long, attenuate into a slender pedicel about as long. — A single specimen of this very distinct species was collected by Prof. W. H. Brewer (n. 1453, in part) in the Shasta Mountains, California; September.

HABENARIA COOPERI. Stout and tall (3 feet high), leafy: flowers numerous, spicate, yellowish green: sepals and petals nerveless, connivent at base, rather thick, equal, 2 lines long; lateral sepals oblong, the upper ovate; lip ovate, truncate at base, with a broad claw; spur short and thick: glands orbicular: beak of stigma triangular: capsule oblong, sessile, 4 or 5 lines long. — On clay hills near San Diego, California; Dr. J. G. Cooper. A strongly marked species, allied to *H. hyperborea*, R. Brown. Of the other western species of this genus,

H. Unalaschcensis (*Spiranthes Unalaschcensis*, Spreng., and *H. Schischmareffiana*, Cham.) must include *H. fœtida*, Watson (*Platanthera*, Geyer), and *Gymnadenia longispica*, Durand. Lindley's *Platanthera striata* is to be referred to *H. gracilis* (*Platanthera gracilis*, Lindl.), distinguished by its short saccate spur.

Sisyrinchium bellum. Stems ancipital, ½ to 2 feet high or more, smooth or scabrous on the narrow margins, of a single node or often with 2 or 3 nodes, each node bearing 1 to 4 (usually 2) peduncles: leaves a line or two wide, shorter than the stem; peduncles 2 to 4 inches long, usually about equalling the nodal bract: spathes of two mostly nearly equal bracts, a half to an inch long, scabrous on the keel, 4–7-flowered: segments of perianth about 6 lines long, broad, 3-toothed or sometimes mucronate, light purple, darker below and yellow at base, somewhat pubescent, as also the ovary: stamineal column 3 lines long, purplish, pubescent at base: capsule depressed-globose or -obovoid, 2 or 3 lines long; cells about 10-seeded: seeds irregularly and obtusely angled, roughened, ⅔ line in diameter. — Common throughout California and to the Columbia River; the western equivalent of *S. anceps*, Linn., in the Atlantic States. It strongly resembles the latter species, differing in its generally stouter habit, broader foliage, and larger flowers, in its less mucronate petals, and in its twice larger seeds. It occasionally occurs with scapelike stems bearing a single spathe, simulating the eastern *S. mucronatum*, Michx., which is distinguished by its low and usually very slender habit, the scape always terminated by a single spathe sessile within the terminal longer bract, the flowers small with segments setosely mucronate, and capsules globose; the size of the seeds is about the same in both. The two eastern species are distinct from the Linnean *S. Bermudianum*, as plainly appears on comparison with specimens from the Bermudas kindly furnished by Governor Lefroy. These have a very stout broadly winged branching stem, with leaves 3 lines wide, broad spathes, larger flowers (6 to 9 lines long), and obovate capsules 3 lines long. The Texan *S. minus*, Engelm. & Gray, referred to *S. Bermudianum* by Klatt, is even more distinct, with its low slender very branching habit, small red flowers, oblong capsules, and minute round seeds. There are indications of other species to be found in Florida and the western Gulf States.

Erythronium purpurascens. Leaves undulate, oblong- to narrowly lanceolate, 4 to 6 inches long: scape low, often stout, occasionally divided, racemosely or somewhat umbellately 4–8-flowered or more; pedicels very unequal, the upper becoming 2 to 4 inches long: flowers

light yellow, more or less tinged with purple, deep orange at base; the lanceolate segments spreading, 9 to 12 lines long: anthers oblong, 1½ to 2 lines long, yellow, on very slender filaments: style thickened above, 3-lobed at the summit: capsule erect, narrowly oblong and obtusely triangular, faintly nerved, 1¼ inches long. — *E. grandiflorum*, var. *multiflorum*, Torrey, Pac. R. Rep. iv. 90; Baker, Journ. Linn. Soc. xiv. 298. In the Sierra Nevada: near Downieville, Sierra Co. (Dr. J. M. Bigelow), and frequent in Plumas Co., whence fine specimens have been received from Mrs. M. E. Pulsifer Ames and from Mrs. R. M. Austin. Abundantly distinct from *E. grandiflorum*, and a very pretty species, well deserving cultivation.

PROCEEDINGS.

Six hundred and ninety-second Meeting.

May 30, 1876. — ANNUAL MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters from the following gentlemen: Professor W. D. Whitney, offering the thanks of the American Oriental Society for the use of the hall of the Academy; Dr. Thomas Andrews, expressing his thanks for the gift of the "Works of Rumford;" Messrs. Stewart and Rowland, accepting their election as members of the Academy; and Mr. George S. Hillard resigning his Fellowship.

The Treasurer presented his annual report, which was accepted and ordered to be entered on the records.

The Librarian presented his report, which was accepted.

Professor Cooke presented the report of the Rumford Committee, which was accepted. In accordance with a suggestion contained in this report, it was

Voted, To place six hundred dollars ($600) of the Rumford fund at the disposal of the Rumford Committee to aid Professor H. A. Rowland in a determination of the mechanical equivalent of heat.

The President announced the death of Christian Lassen, Foreign Honorary Member.

On the motion of the Treasurer, it was

Voted, To appropriate from the general fund: —

For general expenses	$2,100
For Library expenses	700
For Publications	1,500

The following gentlemen were elected members of the Academy: —

William Edward Story, of Somerville, to be a Resident Fellow in Class I., Section 1.

Bennett Hubbard Nash, of Boston, to be a Resident Fellow in Class III., Section 2.

Alfred Tennyson, of Freshwater, to be a Foreign Honorary Member in Class III., Section 4, in place of the late Marchese Gino Capponi.

François Auguste Alexis Mignet of Paris, to be a Foreign Honorary Member in Class III., Section 3.

Ernst Curtius, of Berlin, to be a Foreign Honorary Member in Class III., Section 3.

Sir Henry Creswicke Rawlinson, of London, to be a Foreign Honorary Member in Class III., Section 2, in place of the late Christian Lassen.

Arthur Penrhyn Stanley, of London, to be a Foreign Honorary Member in Class III., Section 3.

Eugène Emmanuel Viollet-Le-Duc, of Paris, to be a Foreign Honorary Member in Class III., Section 4, in place of the late Joaquim Jose da Costa de Macedo.

Mark Pattison, of Oxford, to be a Foreign Honorary Member in Class III., Section 3, in place of the late Jean Baptiste Benoist Eyries.

Thomas Hill, of Portland, to be an Associate Fellow in Class I., Section 1.

George Mary Searle, of New York, to be an Associate Fellow in Class I., Section 2.

Henry Larcom Abbot, of New York, to be an Associate Fellow in Class I., Section 4.

Nathaniel Holmes, of St. Louis, to be an Associate Fellow in Class III., Section 1.

Richard Saltonstall Greenough, of Florence, to be an Associate Fellow in Class III., Section 4.

The annual election resulted in the choice of the following officers: —

CHARLES F. ADAMS, *President.*
JOSEPH LOVERING, *Vice-President.*
JOSIAH P. COOKE, JR., *Corresponding Secretary.*
EDWARD C. PICKERING, *Recording Secretary.*
EDMUND QUINCY, *Treasurer and Librarian.*

Council.

JOHN B. HENCK, WOLCOTT GIBBS, CHARLES W. ELIOT, of Class I.

ALEXANDER AGASSIZ, JOHN A. LOWELL, BENJ. E. COTTING, of Class II.

GEORGE E. ELLIS, ANDREW P. PEABODY, CHARLES C. PERKINS, of Class III.

Rumford Committee.

MORRILL WYMAN. JAMES B. FRANCIS.
WOLCOTT GIBBS. JOHN M. ORDWAY.
EDWARD C. PICKERING. STEPHEN P. RUGGLES.
JOHN TROWBRIDGE.

Committee on Finance.

CHARLES FRANCIS ADAMS, EDMUND QUINCY, *ex officio.*
THOMAS T. BOUVÉ.

The following Committees were appointed on the nomination of the President: —

Committee on Publication.

ALEXANDER AGASSIZ. W. R. GOODWIN.
JOHN TROWBRIDGE.

Committee on the Library.

CHARLES DEANE. HENRY P. BOWDITCH.
WILLIAM R. NICHOLS.

Auditing Committee.

HENRY G. DENNY. ROBERT W. HOOPER.

Voted, To adjourn this meeting, at its close, to the second Wednesday in June.

Professor Watson presented a continuation of his paper on "Inland Navigation."

Six hundred and ninety-third Meeting.

June 14, 1876. — ADJOURNED ANNUAL MEETING.

The PRESIDENT in the chair.

The following papers were read: —

On parachlor and paraiodbenzylbromides, by Professor C. L. Jackson.

On derivatives of parabrombenzylbromides, by C. L. Jackson and Woodbury Lowery.

On methyluric acid, by Professor H. B. Hill.

On the salts of methyluric acid, by O. R. Jackson.

The following papers were presented by title: —

On the solubility of sodic and potassic bromides in absolute alcohol, by J. H. Bullard and A. L. Thomsen.

On the atomic weight of antimony, by Professor J. P. Cooke, Jr.

Contribution towards the history of the fluorides of manganese, by W. H. Melville.

Researches on the substituted benzyl compounds, by Professor C. L. Jackson.

On the effect of temperature on the viscosity of air, by S. W. Holman.

On the characters of a new genus of Papaveraceæ, Canbya; also, of certain other new Californian species of plants, by Professor Asa Gray.

Six hundred and ninety-fourth Meeting.

October 11, 1876. — STATED MEETING.

The PRESIDENT in the chair.

Letters were read from Messrs. Curtius, Le Duc, Mignet, Pattison, Rawlinson, Stanley, Abbot, and Searle, accepting their election as members of the Academy; also from Messrs. Bowen and Cabot resigning their membership.

Voted, To place six hundred dollars ($600) of the income of the Rumford Fund at the disposal of the Rumford Committee to aid Professor Langley in his researches on radiant energy.

Professor A. G. Bell, by invitation presented a paper on telephony.

On the motion of Mr. Emerson it was

Voted, To heartily congratulate Professor Bell on his wonderful discovery in telephony.

The following papers were presented: —

On the use of glass circles for meridian instruments, by Mr. W. A. Rogers.

On the suspension of a ball in a jet of air having an inclination of 45° by Mr. W. A. Rogers.

On a new edition of Ptolemy's catalogue of stars, by Mr. C. S. Peirce.

Dr. Gray presented, by title, the following paper: —

Contributions to North American Botany.

Six hundred and ninety-fifth Meeting.

November 10, 1876. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary announced the death of Nicholas St. John Green, William A. Stearns, and Edward Wigglesworth, Fellows of the Academy; also of Charles Davies, Associate Fellow, and Christian Gottfried Ehrenberg, Foreign Honorary Member. He also read letters from Monsieur G. A. Hirn acknowledging the receipt of the Works of

Count Rumford, and from Dr. F. Garrigou, requesting the Academy to send him samples of the principal American thermal springs. This last was referred to the Smithsonian Institution.

Professor John Trowbridge, on behalf of Professor J. D. Whitney, presented a paper on the velocity of the shock of the Hell-Gate explosion.

Mr. W. A. Rogers exhibited a series of drawings of the planet Jupiter, by Mr. L. Trouvelot; he also presented, by title, a paper, by Mr. L. Waldo, on the pitch of the screw of the micrometer of the equatorial of the Harvard College observatory.

Mr. S. P. Sharples presented the following papers by title: —

On the aceto-arsenite of copper.

On some further determinations of standard milk.

Six hundred and ninety-sixth Meeting.

December 13, 1876. — MONTHLY MEETING.

The PRESIDENT in the chair.

The President read a letter from Mr. Alfred Tennyson, accepting his election as Foreign Honorary Member; also, a letter from Mr. William Ferrel, resigning his fellowship.

The following papers were presented: —

On the structure of the chrysalis of butterflies, by Mr. S. H. Scudder.

On the two-point and three-point problem in surveying, by Professor E. C. Pickering.

On the water of the ponds of eastern Massachusetts, by Mr. S. P. Sharples.

Six hundred and ninety-seventh Meeting.

January 10, 1877. — STATED MEETING.

The PRESIDENT in the chair.

The following papers were presented: —

On the micrometer level, by Professor E. C. Pickering.

On vortices, by Professor John Trowbridge.

On tri-iodo-resorcin, by A. J. H. Norton, presented by Professor E. N. Horsford.

On the mythology of the North American Indians, by Professor J. W. Powell.

The President announced the death of Professor Alexis Caswell, of Providence.

Voted, To adjourn this meeting, at its close, to the second Wednesday in February.

On the suggestion of Professor F. W. Putnam, it was

Voted, To refer to the Council the question of depositing a Mexican mask and a plate of Dighton Rock in the Peabody Museum of Archæology.

Six hundred and ninety-eighth Meeting.

February 14, 1877. — Adjourned Stated Meeting.

The President in the chair.

Sir James Paget, of London, was elected a Foreign Honorary Member in Class II., Section 4, in place of the late Gabriel Andral.

On the motion of Professor Lovering, it was

Voted, That a committee of three be appointed to consider and report upon the expediency of memorializing Congress to pass a law making it the duty of postmasters to collect the facts in regard to accidents to life or property by lightning which may occur within the area covered by their departments, and communicate the same as may hereafter be designated.

A committee was appointed consisting of Messrs. Lovering, Bigelow, and Pickering.

Dr. Thomas M. Brewer read a paper on parasitic birds.

Professor A. Graham Bell, introduced by the Recording Secretary, presented a description of his further researches in telephony.

Dr. Williams, on the introduction of Dr. B. E. Cotting, read a paper on French verbs.

Six hundred and ninety-ninth Meeting.

March 14, 1877.—STATED MEETING.

The PRESIDENT in the chair.

The President announced the death of Alexander Braun, Wilhelm Hofmeister, J. C. Poggendorff, and Karl Ernst Von Baer, Foreign Honorary Members; and of C. H. Davis, Charles Wilkes, and F. B. Meek, Associate Fellows.

The following gentlemen were elected members of the Academy:—

Alexander Graham Bell, of Salem, to be a Resident Fellow in Class I., Section 3.

Jeremiah Lewis Diman, of Providence, to be an Associate Fellow in Class III., Section 3.

William Ferrel, of Washington, to be an Associate Fellow in Class I., Section 1.

The Treasurer read a letter from the Hon. E. B. Washburne, giving an account of the repairs which he had caused to be made at the expense of the Academy of the monument of Count Rumford at Paris.

The following papers were presented:—

A mathematical discussion of vortex rings in liquids, by Professor John Trowbridge.

Upon an application of Lane's law of the accumulation of solar heat, by Professor Benjamin Peirce.

On systematic errors in star declinations, by Professor E. C. Pickering.

Antigeny; or, sexual dimorphism in butterflies, by Mr. S. H. Scudder.

On a new form of clock escapement, by Professor C. A. Young.

The following papers were presented by title:—

Theory of the horizontal photoheliograph, including its application to the determination of the solar parallax by means of transits of Venus, by Professor William Harkness.

On a base from the residues of aniline, by Professor C. L. Jackson.

On a method of measuring electro-motive power by B. O. Peirce, Jr.

A note on the conduction of heat in a solid, by B. O. Peirce, Jr.

Seven hundredth Meeting.

April 11, 1877. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters from Messrs. Diman, Ferrel, and Paget, accepting their election into the Academy.

On the motion of the Treasurer it was

Voted, That the thanks of the Academy be presented to the Hon. E. B. Washburne and to Mr. Riggs for their services in connection with the repairs of the monument of Count Rumford in Paris.

The following papers were presented: —

On the haloid compounds of antimony, by Professor J. P. Cooke, Jr.

On the temperature of a perfect gas which is in convective equilibrium, by Professor Benjamin Peirce.

The following papers were presented by title: —

On parabrombenzyl compounds, by C. L. Jackson and Woodbury Lowery.

On furfurol formed in the dry distillation of wood at low temperatures, with a note on Scanlan's pyroxanthin, by Professor H. B. Hill.

On some new algæ of the United States, by Professor W. G. Farlow.

Mode of germination in the genus Megarhiza, by Professor Asa Gray.

Seven hundred and first Meeting.

May 9th, 1877. — MONTHLY MEETING.

The VICE-PRESIDENT in the chair.

Messrs. Cooke, Eliot, Agassiz, Ellis, and Perkins were appointed a committee on nominations.

The Recording Secretary declined to be regarded as a candidate for re-election.

The following papers were presented: —

On the iodides of antimony, by Professor J. P. Cooke, Jr.

On the chemical relations of pressure, by Professor T. S. Hunt.

On adiabatic surfaces, by Professor John Trowbridge.

On the preparation of nitrogen gas, by Professor Wolcott Gibbs.

On diamido-sulphobenzide-dicarbonic acid, by Arthur Michael and T. H. Norton, presented by E. N. Horsford.

On paraiodbenzyl compounds, by Professor C. L. Jackson and Mr. C. F. Mabery.

On some new algæ new to the United States, by W. G. Farlow.

Descriptions of new species of plants with synopses of certain genera, by Sereno Watson.

The following paper was presented by title: —

Characters of some new, or little known, genera of plants, by Professor Asa Gray.

The Corresponding Secretary presented the following annual Report of the Council: —

REPORT OF THE COUNCIL.

SINCE the last report, May 10, 1876, the Academy has lost by death fifteen members, as follows: four Fellows, Nicholas St. John Green, W. A. Stearns, Emory Washburn, and Edward Wigglesworth; five Associate Fellows, Alexis Caswell, Charles H. Davis, Charles Davies, Fielding B. Meek, and Charles Wilkes; six foreign Honorary Members, Braun, Ehrenberg, Hofmeister, Lassen, Poggendorff, and Von Baer.

NICHOLAS ST. JOHN GREEN.

MR. NICHOLAS ST. JOHN GREEN, Professor at the Boston Law School, and formerly lecturer at the Harvard Law School, died at Cambridge, on the 8th of September last. Although his name was only beginning to be known to the public, yet, to the eyes of his associates, he occupied, at the time of his death, as important a position in the field of jurisprudence as did the equally lamented Chauncey Wright in that of philosophy; and in the sudden deaths so near together of these intimate friends in the prime of life, the Academy has lost two of its most gifted members.

In the early practice of his profession, Mr. Green acquired a critical knowledge of the criminal law; and he undoubtedly started with a superstitious respect for the technical element which still prevails in that part of the law. In fact, it would seem evident that, as a younger man, he must have held a good many of the prejudices, legal and political, which are natural to a strong nature unchastened by learning and reflection. But his reason was stronger even than his temperament; and as time went on, and he became a student of history, political economy, psychology, and logic, prejudice gave way to philosophy, and his convictions, without losing in strength, were tempered by an appreciation of the other side which powerful men do not always acquire.

He handled a question of law not only with the mastery of a logician who easily reduced a case under established principles, but, also, and with equal power, in the light of the history which explains those principles, and the considerations of political science and human nature which justify them. The evidence of his ability was not confined to the lecture-room; for it is not too much to say, that no man at the Suffolk bar produced a greater effect upon the opinions of the Supreme Court, in the cases which he presented, than he. His arguments, in addition to the qualities of substance which we have mentioned, had a terseness and simple beauty of form which it is impossible to compare with any less-distinguished models than those of Judge Curtis. Mr. Green did not live long enough to construct a systematic work; but as, with him, theory was not an excuse for ignorance of details, but was based as much on exact and practical knowledge as it was on broad and careful study outside the law, those who knew him best hoped and expected that, when he was satisfied with his patient preparation, he would produce results worthy of his talents. A few notes to his two volumes of criminal cases, two or three articles in the "American Law Review," and three model volumes of reports, are all that the profession can judge him by; and they are, perhaps, enough. But those who have had the benefit of his conversation and criticism know that, although he had already justified the opinion of his friends, he gave promise of still greater achievements with which he might have enriched the world and honored his profession had he lived.

"He was such a philosopher as needs a Diogenes Laertius to portray him," writes, in a private letter, one who was familiar with his modes of thought. "The basis of his philosophy was, that every form of words that means any thing indicates some sensible fact on the existence of which its truth depends. You can hardly call this a doctrine: it is rather an intellectual tendency. But it was Green's mission to insist upon it and to illustrate it. This was his guide, I feel sure, in the study of law. Witness his essay on the doctrine of responsibility. And he desired to apply the same principle to other branches of philosophy, — to Logic, to Psychology, &c. But these subjects he did not choose to follow out for himself into detail. He cared for them chiefly as fields to assert his ruling principle in: beyond that, he was more or less out of his province. He rather undervalued systems; prizing more highly brochures which put some single principle in a strong light. Bentham's refreshing manner of searching for realities, and contemptuously tossing aside formal doctrines of the law in rummaging down to the very pleasures and pains which result from different

legal arrangements, greatly pleased him. But he did not much care for Bentham's systematic works: it was rather his horde of pamphlets, raiding like Cossacks into the legal realm, which delighted him. So, of political economists, he most admired Jean Baptiste Say, perhaps because he was a great pamphleteer.

"Green carried the same keen scent for sensible facts and contempt for every thing else into his affections and his tastes. He was a most warm-hearted man, with an abounding sympathy for all sorts of people, a great fondness for children, and a love for animals. He had also a fine taste for poetry, of which he had read a great deal. But one did not at first so much note his delicate appreciation of what was real, as his scorn for all that was unreal. He had a quality, which was certainly not roughness, but which, for want of a better appellation, might be called a Socratic coarseness. It was well fitted to be the sturdy support of his realism, and gave one a positive pleasure when one knew him, as if it had been an artistic study. He had an overflowing spirit of good-fellowship, and a Rabelaisian humor, without the Rabelaisian cynicism. I see him now, as he draws back from a game of whist, his genial nature shining through the merry twinkle of his eye. But, as he speaks, one perceives that it is not pure mirth that moves him, but sympathetic amusement; for his talk is generally of some fine observation of human or animal nature. . . . He was wont to take up prostrate or hopeless causes with a zeal, unwise and Quixotic from a worldly point of view, but which exemplified some of his highest traits."

WILLIAM AUGUSTUS STEARNS.

The Reverend William Augustus Stearns, D.D., LL.D., President of Amherst College, died at Amherst, June 8, 1876, in the seventy-second year of his age. The genealogy of Dr. Stearns would add another proof, were such necessary, to the truth of the doctrine of the transmission of moral and intellectual qualities, and even of tendencies towards particular pursuits, by hereditary descent. He came by the side both of his father and his mother of long lines of Congregational ministers, devout and learned men, not inexperienced in the ways of mankind and the management of worldly business, from the part taken by the ministers of the old Congregational Establishment in the administration of the affairs of their parishes and often of their parishioners. The Triennial Catalogue of Harvard College contains the names of graduates, *nomina literis italicis exarata*, scattered along the ranks of the eighteenth century and reaching back into those of the seven-

teenth, through whom Dr. Stearns traced his lineage. The earliest of all of his cis-Atlantic progenitors was of a time preceding the foundation of the College, — the Rev. John Woodbridge, who came to New England in the year 1634, and was the first minister of Andover in this State. Descended from ancestors educated in the best learning of their times, spending their lives in a profession which involved responsibilities, practical and secular, as well as moral and religious, it would have been strange if his mind and character had not had impressed upon them the qualities for which he was distinguished during his life. He was in a manner preordained to be a minister and the head of an institution of learning from his birth.

The father of Dr. Stearns was the Rev. Samuel Stearns, who graduated at Cambridge in the year 1794, and his mother was the daughter of the Rev. Jonathan French, long the minister of Andover. Mr. French had begun his active life in the military service of the Province, and was Sergeant in the garrison which was maintained at the Castle in Boston harbor, when he was moved to exchange the sword of the flesh for that of the spirit; and, after graduating in 1771, he was ordained minister of Andover as above. Mr. Stearns was settled over the town of Bedford, in this State, with a salary of three hundred and thirty-three dollars and thirty-three cents. The town further gratified him with a loan of a thousand dollars without interest, which probably enabled him to purchase a farm of twenty acres to help in the support of his family. That some addition to his meagre stipend was convenient may be inferred from the fact that his children were thirteen in number, of whom eleven grew up to adult age. His farm he made a part of the physical education of his boys, and of their moral education as well, they assisting him, as they successively attained the proper age, in its cultivation, which he carried to a high degree of perfection. Notwithstanding the narrowness of his means, Mr. Stearns managed to send four of his five sons to Harvard, three of whom were ministers, and eminent in their profession. Of the sons, William, born March 17, 1805, was the second. He showed an early love of study and an extraordinary power of memory, some remarkable feats of which were remembered in the family; such as his knowing the Assembly's Catechism perfectly at six years old, a curious example of purely verbal memory, as it was impossible that he should have attached any meaning to most of those doctrinal apophthegms at that childish age. A little later he learnt by heart the Gospel of Luke in one week in the intervals of his farm work and other occupations. A more characteristic attempt of his was made on the outworks of good

learning by getting surreptitious possession of *the* Latin grammar, — for the good minister's means admitted of but one for all his sons, — and secretly beginning the study of Latin by himself, an effort which proved to be quite beyond his boyish strength.

When young Stearns reached the age at which his brothers had been sent to Phillips Academy, in Andover, where his father also had had his school education, he naturally asked to be allowed to go thither in his turn. But his father, oppressed by the *res angusta domi*, replied, sadly, "My son, desirous as I am of doing what you ask, I do not see that Providence opens the door!" "I do not believe, sir," replied the boy, "that Providence will open it, unless you knock!" Struck by the spirit or the good sense of the answer, the father knocked in faith: the door opened and remained open until the son had passed through the school and afterwards through the college. It was a favorable time when the boy of fifteen took up his abode in that beautiful town, which Improvement had as yet spared, and where he spent three happy and profitable years. The academy was then under the mastership of the excellent Principal, John Adams. The government of this gentleman differed from that of most masters of his time and before and since. His rule, though firm and decided, was gentle and kind. Corporal punishment was almost unknown, and inflicted only in cases of the grossest misconduct. He did not permit the principle of rivalship and emulation as motives of action. There was no head and no foot to classes, no medals or rewards of merit, no parts at the Annual Exhibition distinguishing degrees of scholarship. His pupils were expected to study because it was their duty and what they were at school to do. He thus saved them from the jealousies, heart-burnings, and disappointments which so cruelly wring the breasts of very young persons. At the more mature age of young men in college, the case may be different, and such contentions and prizes may be fitting preparation for the conflicts of life. But for young children we are satisfied that Mr. Adams's philosophy is the wise and true one. His system justified itself by its success. The scholarship of his pupils was quite equal to the best of his time. We believe that there was never an instance of one of his scholars failing at the examinations for admission to college, and in college they won their fair share of college distinctions. In his old age his Alma Mater, Yale College, gave him the degree of Doctor of Laws, an honor which she might have gracefully bestowed forty years sooner, when, besides being a compliment and a gratification, it would have been a professional advantage. For he was a most dutiful son of that mother of his mind, and always did what he

properly could to determine the steps of a questioning pupil in the direction of her academic shades.

Under these gentle and gracious influences, young Stearns spent three diligent years, and at the Commencement of 1823 he entered Harvard College to pass four other diligent years of studious preparation for his work in life. From the first he took a high rank among his fellows. His preparation for the exercises of the class-room was always thorough to perfection, and his recitations accurate, elegant, and fluent, but without any studied attempt at display. Though not recluse, he was retired in his habits, and devoted himself earnestly to the work that he was there to do. Though his intimates were few, there was no man of his time more cordially esteemed and respected of all that knew him than he. The chief drawback on the happiness of his well-spent hours was the narrowness of his circumstances, which more than once threatened to cut short his college career. At the most critical moment, however, when he was brought face to face with this cruel necessity, he was relieved from his distress by the timely and judicious generosity of President Kirkland. By dint of keeping school in the winter vacations and of the most rigid economy he managed to win his way to the end, and he took his degree at the Commencement of 1827 with the third honor of his year. If his worthy master, Mr. Adams, had entertained any fears — which it is altogether probable that he did — that his promising pupil might be shaken in his faith in the strict theology of his fathers through the heretical influences to which he was subjected at Cambridge, he was happily disappointed; for the young Bachelor of Arts issued from the furnace without the smell of fire upon his garments. Indeed, we imagine that it would have been necessary for him to court the flames to have had his garments even singed by the fires of heresy. We believe that there was never the slightest attempt at proselytism made by the heresiarchs of the college. Even attendance on the theological lectures of Dr. Ware, which were necessarily imbued with Unitarian ideas, was not required of students who objected to their doctrine. However this may have been, Mr. Stearns remained faithful to the religious tenets he had imbibed in youth, in which he was assisted by a society of young men of Evangelical views, which met weekly for devotional purposes and to strengthen one another to hold fast to the faith as delivered to the Fathers.

After a year's interval of school-teaching, Mr. Stearns joined the Theological Seminary at Andover, and went through the regular course of three years. Having received his license to preach in 1831, and

gone forth into the world to seek a fit field for his labors, he showed in the choice of one his characteristic wisdom and moderation. He was ambitious rather of doing effective work in his calling than of winning the high prizes of his profession. He preferred to build up the waste places rather than to enter into the rewards of other men's labors. Instead of continuing to preach as a candidate in the expectation of securing one of the metropolitan parishes, which his learning, his character, and his gift of pulpit eloquence would almost certainly have procured for him, he cast in his lot at once with a young and struggling congregation in Cambridgeport, which had little to offer him excepting an opportunity for work and friendly co-operation in it. His superiors in the profession, among them at least one of the professors at Andover, marvelled at his choice, and looked upon it as a throwing away of himself and his gifts and graces. And, indeed, Cambridgeport was not at that time the thriving and populous settlement that it has since become. There was little that was inviting to the eye or to the taste in the straggling streets and flat surroundings of that uninteresting suburb. Such as it was, however, there it was that Mr. Stearns set up the staff of his rest and entered upon what he had accepted as the business of his life. His neighborhood to Boston and Cambridge, it is very likely, was a consideration which may have had some weight in his decision. He began his ministerial life with a salary of seven hundred dollars and a proportion of the pew-lettings, — a provision scarcely more ample, the difference in the value of money considered, than the humble stipend which was thought sufficient for the modest needs of his father at Bedford, nearly forty years before. Here Mr. Stearns remained for twenty-three years, beloved of his people, respected by his neighbors, and useful in various directions outside of his vocation. Besides being chairman of the School Committee of the town, he was a member of the State Board of Education and an Overseer of Harvard University under the charter as modified in 1810. The twenty-three years of the pastorate of Mr. Stearns were years of great success in his function. He built up his congregation from the feeble beginnings of the commencement of his ministry to be one of the most prosperous and flourishing in the neighborhood of Boston. And he had provided for himself a convenient and pleasant home.

While thus happily situated and usefully employed, doing well what he loved best to do, Dr. Stearns — for his Alma Mater had given him the degree of Doctor in Divinity the year before — was invited in the year 1854 to assume the Presidency of Amherst College. The offer

of so important a position was naturally gratifying to him as a testimony of the most eminent men in his denomination to their belief in his qualifications for such a post, but its consideration could not be entertained without a painful conflict of contending personal feelings and professional duties. The unwillingness of the congregation he had so successfully built up to part with him, and his own reluctance to leave a scene where he had done and enjoyed so much, for a new and untried field of labor, embarrassed the decision of a question so material to his future with many conflicting emotions and considerations. Happily for himself and the college, his deliberate judgment was in favor of the acceptance of the Presidency, and he entered upon its duties in November, 1854. If the governing authorities of the college had ever doubted Dr. Stearns's eminent qualifications for the wider field of activity they had opened to him, they very soon learned from his official conduct how wise and fortunate their choice had been. By nature, by education, and by experience of men, he was eminently fitted for the oversight and direction of an institution for the higher education of youth. Learned, and a lover of sound learning, standing by preference upon the ancient ways of academic teaching, but not stubbornly tenacious of them, he was ready to consider and accept the newer ideas and methods which European influences and the growing claims of the physical sciences are urging upon the educators of the day, to the degree and in the manner that seemed to him best adapted to the present condition of education in this country.

While he was thus at once wisely conservative and judiciously progressive in his dealings with the more recent theories of academic instruction, his personal and official relations with the undergraduates were of the most kindly and paternal description. His native courtesy and winning suavity of manners won for him their affection and confidence whenever they came into personal contact with him. His weight of character and sound judgment impressed them with a sense of his sagacity and wisdom in all his counsels and suggestions. His very presence bore the stamp of perfect uprightness and absolute truthfulness. He held that to be the best government which governs the least, and his endeavor was to make his students a law unto themselves and to teach them to rule their spirits and their lives by the laws of self-respect and right reason. But when discipline was needed to maintain the good order or the good reputation of the college, he could be as stern and severe as Justice herself. The transgressor found that his way was hard when he had incurred the just displeasure and judicial censure of the President. His heart's desire was to prevent misrule

or disorder by his moral influence over the minds of his students, but yet so that they should understand it to be deliberate wisdom and not timid policy that inspired his mild rule, and that the severities of discipline were at hand for the vindication of the laws in the last resort. Personal instruction of the students in the class-rooms was not to his taste, and he had no special gift in this direction, and he largely left that office to those to whom nature or experience had made it easy. In planning, directing, and superintending the teaching of others, he found his more congenial and appropriate employment as the head of the college. In these duties, and especially in the exercise of the most important function of the president of a college, that of the selection of the instructors and officers who are to work under his supervision, he used his constitutional diligence and evinced that instinctive knowledge of men and that intuitive discernment of spirits which leads to the filling of the right places with the right men at the right time.

Besides the qualities at which we have glanced, which eminently fitted President Stearns for the headship of an institution of good learning, he had others which enabled him to do his college most material service. He had a natural turn for affairs and was an admirable man of business. Under his presidency, the funds of the college were very largely increased, the number of students and of teachers more than doubled. The college buildings are twice as many as at his accession to office. The departments of instruction have been enlarged and extended in every direction. While holding firmly to the sound orthodox faith that a knowledge of the ancient languages is the indispensable foundation of a truly liberal education, the departments of the modern languages and literatures, of theology, astronomy, the physical sciences, of history and philosophy, and of the science of government, were all of them reinforced, and some of them established during his incumbency. The importance of the fine arts and antiquities as a part of education was first recognized in his time, and a museum established for the promotion of those elevating and refining pursuits. The long-neglected but most important study of hygiene and the physical education which belongs to it received under him the attention it deserves, and with excellent results in the improved health of the students. The marked advance which Amherst College has made within the last quarter of a century and the high rank it holds among the academic institutions of the country may be said, without disparagement of his eminent predecessors, to be mainly owing to the zeal and labors of President Stearns. The interests of his own college, however, did not absorb his attention, to the neglect of those of

education elsewhere. He again served on the State Board of Education, and it was he who first proposed the Annual Convention of College Presidents to compare and discuss opinions as to matters of interest common to them all.

When the civil war broke out, President Stearns was not slow to discern the needs and the duties of that hour of crisis. Though he calmed the first enthusiasm of his young men who wished to answer at once the first call of the country, yet as soon as the urgency of the case was manifest, and it was clear that an appeal to arms was inevitable, he encouraged the enlistment of his students, and sent them to the field with his blessing and hearty God-speed. And he did not withhold the sacrifice of his own son when duty to his country called for it. His youngest son, Frazar A. Stearns, then an undergraduate, went to the front as Adjutant of the 21st Massachusetts Regiment. After a brief but brilliant term of service this gallant youth fell at the battle of Newbern on the 14th of March, 1862, in the twenty-second year of his age. His father met this cruel calamity in a true spirit of Christian patriotism. His loyalty to the Union was but strengthened and made more active after it was thus sealed by the blood of his son. He might have said with the old Duke of Ormond on losing his son the Earl of Ossory, "I would not exchange my dead son for the living son of any man in Europe!" General Burnside gave one of the guns captured by the men under Adjutant Stearns's command to the College as an expression of his sense of the merit of the young officer and as a fitting monument to his memory. This household offering to his country gave force and touching energy to the patriotic words which the President never failed to utter in the hour of need. He never failed to enforce the Christian duty of citizens to do their part in the political as well as the military service of the nation in his Baccalaureate and other addresses to the youth who sat at his feet.

It will be seen, from this imperfect sketch of the career and the character of President Stearns, that he had been singularly fortunate and happy in his life. And he was equally happy and fortunate in his death. He certainly died at his post, if ever man did. He was conducting the college prayers on the morning of his death, when arrested by the illness of which he died before the sun went down. In the fulness of his powers, in the bosom of his family, with every consolation that religion, domestic affection, and friendship could afford, with little pain and no fear, his useful and honorable life came to a tranquil and happy close. It was a true Euthanasia.

The natural endowments and literary attainments of President

Stearns were of a high order. His sermons and occasional addresses, many of which have been published, show great clearness of thought, accuracy of reasoning, force of illustration, and rhetorical skill. But he was even more distinguished as a ready debater and brilliant extempore speaker. He had great quickness of thought and remarkable fluency and felicity of speech. It is related of him that, while yet at Cambridgeport, he was told while on his way to church of the death of Daniel Webster. He at once laid aside the sermon he had prepared, and delivered an unpremeditated discourse upon the dead orator, which his hearers regarded as not inferior to any of the more elaborate efforts of the eminent men who followed him on the same theme. On another occasion, at a public meeting where Mr. Webster and Mr. Everett had swayed the audience with their words of power, Mr. Stearns was called for after the crowd began to disperse, and he held them long in eager attention, not less earnest and enthusiastic than that commanded by the great speakers who had gone before him. The moral and personal qualities of President Stearns, however, were those that endeared him most to his friends and enabled him to do the excellent work that filled his days, and to win the success that crowned his life. His personal and moral courage was perfect. He feared nothing but doing wrong. His success in the various activities of his life was owing not so much to the preponderance of any one quality of his character as to the balance and proportion of them all. His soundness of judgment, his absolute integrity and perfect truthfulness, his unfailing common sense, all contributed to give him that weight of character which made his voice potential in all matters of practical or academical detail. He was firm and persevering in matters about which he had deliberately made up his mind, and he generally carried his points; but it was because they were points that ought to be carried. His nature was singularly rounded and complete. His demeanor was marked by a modest dignity which claimed what was due to himself, while giving to others all that was due to them. Courteous of speech, gentle and polished in manner, cheerful in conversation, thinking and speaking no evil, yet capable of sternest indignation at injustice, cruelty, or meanness, President Stearns left to his academic children, to his friends, and to the world an example of a highly educated, high-principled, high-bred Christian Gentleman.

EMORY WASHBURN.

EMORY WASHBURN, Governor of Massachusetts, and Professor in the Harvard Law School, was born during the first year of the present century, amid the simple life of one of the hill towns in the interior of the Bay State. He received a collegiate education first at Dartmouth and afterwards at Williams Colleges, from which he graduated in 1817; he studied law at the Law School of Harvard College, and entered upon the practice of his profession in his native town of Leicester. In a few years he removed to Worcester, where for many years he possessed the confidence of the tribunals and the community, and had, perhaps, the largest practice in this, the central county of the State, at a bar always eminent for the character and ability of its members. He was sent to the Massachusetts House of Representatives both from Leicester and from Worcester; and was subsequently elected to the State Senate, for Worcester County. Soon after he was appointed a judge of the Court of Common Pleas, an office which he held for four years; and in 1853 he was elected Governor of the State. In 1854, the degree of Doctor of Laws was conferred on him by his Alma Mater, and also by Harvard College. During this period of active life, in addition to his arduous professional and official duties, he gave freely of his time and support to all the best interests of society.

From such a career, at the ripe age of fifty-six, he became a Professor in the Law School at Cambridge, and remained in that position for twenty years. To it he brought the fruit of a long and honorable life; to it he brought also the character which had made that life so truly honored, besides that warmth of the most abounding personal sympathy, and that devotion to his work which seemed more the prompting of his nature than the command of duty. These twenty years were the crown and glory of his life. And when, a year ago, at the ripe age of seventy-six, he resigned his chair, because *he* felt that it might better be filled by a younger man, his associates could discover no abatement of force in mind or body. And such an active nature could not remain idle or be spared from the public service. After an interval of fifty years since his first election, he was returned to the Legislature of his native State by his fellow-citizens of Cambridge, and there with all the vigor of a youth he entered upon the arduous duties of Chairman of the Judiciary Committee of the House. While full of activity in manifold ways, both in public official duties, in private life, and in numerous associations for the promotion of the best interests of society, and amid friends and home, he received the last summons, and, through a short

illness, passed into the other life. Such is the outline of his career; what work has he left behind him?

The work of such a man and teacher it is difficult to trace. It has mingled with the characters and minds of his pupils. Words of sympathy and wisdom, fitly spoken, have turned the current of many a life from waste to blessing. It is the very presence of his life and character, rather than his intellectual processes, which influences those around such a man as Emory Washburn. Yet some things may be definitely said of the result.

In the school where the great work of his life was done, he was ever so free-hearted in giving his sympathy and counsel to all who, from year to year, needed or sought it; his usefulness in this respect was so transcendent that, by universal consent, he is pronounced the best beloved of all the teachers that school has ever had. His devotion was not to the ideal entity of the Institution, whose being is to live through the centuries. That might secure the devotion of more poetic minds. His labor of love was with and for the young men who resorted to it, full of the mingled hopes and fears that attend their entrance upon life, coming often from the *res angusta domi* to secure encouragement and aid in the new and brief home where he was always found a father and a friend. Among the teachers of that school who have gone to their rest were Ashmun and Story and Greenleaf and Parker and Sumner; yet so well known to the living that the name of each is a biography. Of those yet living, his companions in instruction, we may not speak. They, with the thousands of his pupils, will concur in the inscription to his memory, that he was the best beloved of all the teachers of this school of the law.

But a more specific and definite work he has done for the country at large, for our English-speaking race, for its body of jurists, and the administration of justice. His instructions in the school were chiefly given in the most difficult department of the law, — that of real property; the most difficult to us, because it does not grow out of the convictions or practices, or needs of our age or of our institutions, alone. It comes to us from other ages, from other political and social organizations, from other ideas of right, from other views of the nature and obligations of property, and specially of landed property. Its system of rules is, therefore, composite and intricate; and not always reasonable to our minds, or even useful to existing interests. The needs of the present, and a forecast of those of the future, are innovating upon it, changing it, not always wisely. A remedy for one evil often admits greater evils into such a system of

law. Most of the law of personal property, on the contrary, is the growth of modern times, suited to the wants of the present; or, in fact, but an adoption into the law of the life of the age. Its ideas become action; its action becomes the law. The law follows the fact; becomes its transcript and record. Not so with our law of real property. Some law of real property is everywhere essential: decisions upon it following the ancient precedents, bending to the emergencies or legislation of recent times, are issued in scores of volumes with every year. The labor which will carefully study and collate them all; which will sever the essential from the incidental part of each of these decisions; which will collect, in two or three volumes, the substance of all of them; which will endeavor to mould them into a harmonious system, for the guidance and instruction of the profession, the courts, and the community, — such labor, indeed, requires, in the first instance, a most faithful conscience in him who has undertaken such a work. That faithful conscience Professor Washburn had; that immense labor was conscientiously performed. And the result is contained in his work upon the "Law of Real Property," now in three volumes; and in the supplementary work on "Easements and Servitudes." It is one of the most useful works on that subject, both for the bar and for the public; the most useful practical work upon this subject which exists in the English language. The faithfulness of its citations saves an amount of time for those engaged in the administration of justice, and for those whose interests are involved in such administration, which exceeds any estimate.

A more forcible and less conscientious hand might mould the mass into more symmetrical form. Professor Washburn's duty was not to make the law, but honestly to report it as others declared it to be. "Blackstone's Commentaries" were written for students. The clear and easy flow of their style is yet unexcelled among expositions of the law; for the law deals not with the graceful sentiments of life. It has no æsthetic side. It is devoted to the stern demands of justice, and to practical interests. Professor Washburn's style in recording its decisions was, like that of most law-writers, —

"Subdued
"To that it works in, like the dyer's hand."

Professor Washburn's influence upon the young men who commenced with him the manly study of the law, and who are yet ascending the paths of life; the great tribute, rather than debt, which he paid to his profession and to the cause of justice, which is the first inter-

est of civilized society, — these are the works of his life. To the results of them no limit can be easily assigned.

His friends (no one could know him, and not call him friend) all recognize that these crowning works of his life had their origin in the governing elements of his character, — devotion to duty and good-will to man. In him, wisdom and charity in its largest sense were most completely blended. His life, moreover, was fully rounded and his work well done. As he often expressed the wish, he died before "his eye was dim or his natural force abated." Never to have known weariness during a life of nearly fourscore years, full of usefulness, honor, and domestic comfort, is as great a blessing as ever falls to the lot of man, and this blessing Judge Washburn fully enjoyed.

EDWARD WIGGLESWORTH.

Edward Wigglesworth, a Fellow of the Academy of Class III., Section IV., died at his residence on Sunday, October 15, 1876, in this city, where he was born, January 14, 1804. He was in his seventy-third year.

His ancestral and family name connects him with individuals conspicuous and honored in their several generations, from the first settlement of the country, for their characters and services in the various ranges of life. His first progenitor in this country was Edward Wigglesworth, from Yorkshire, in old England, who, coming to Charlestown in this colony in the summer of 1638, removed in the autumn to New Haven, where he died, October 1, 1653. A stone in the Green in that place, marked with the initials "E. W.," was long supposed to designate the grave of Colonel Edward Whalley, a member of the High Court of Justice which condemned Charles I.; but it is now reasonably believed to denote the grave of the first Edward Wigglesworth. Among the children whom he brought with him to this country was one, then nearly seven years, who, bearing the name of Michael Wigglesworth, won great distinction in this colony as divine, physician, and poet. Having been trained by the famous school-master, Ezekiel Cheever, whose service as a pedagogue in New England covered a period of nearly seventy years, Michael became, in 1647, one of the earliest of the students in Harvard College. Graduating in 1651, he became a tutor and a Fellow of the college, while preparing for the ministry. Having labored for a season in the instruction of the Indians at Martha's Vineyard, he was ordained as pastor of the church in Malden, in this colony, in August, 1656. Here, after a long service, he died in office,

June 10, 1705. Though he was noted for his skill and efficiency in the medical practice of those days, he could not explain the nature of the malady which made him for most of his life a sufferer from a mysterious form of invalidism which interrupted his professional work, and caused him to make a voyage to Bermuda. As the poet of his age and country, he was the author, among various other compositions, of that which, under the title of "The Day of Doom," was the classic for children and their parents for more than half a century in New England.

Edward, the youngest son of Michael Wigglesworth, was inaugurated in 1722 as the first divinity professor in Harvard College, where he had graduated, on the foundation of Thomas Hollis, Esq., of London. Dr. Wigglesworth having held this office for more than forty years, was succeeded in it, in 1765, by his son, Dr. Edward Wigglesworth, Jr., who, in 1791, had, as his successor in it, the Rev. Dr. David Tappan, who was a great-grandson of Rev. Michael Wigglesworth, till 1803. Thus, for a period of eighty years, descendants in three generations from the old Malden divine filled one of the places of highest influence and responsibility in this colony, province, and State of Massachusetts. The second Prof. Wigglesworth was one of the original Fellows of the Academy, at its incorporation. Papers contributed by him appear in the earlier volumes of the Memoirs. His calculations for the construction of Life Tables were especially valued. Thomas Wigglesworth, a graduate of Harvard in 1793, who studied law, but afterwards, in wide commercial business, became one of the most honored and successful merchants of Boston, was the youngest son of the second Professor Wigglesworth. The subject of this Memoir was the oldest son of Thomas, by his wife, Jane Norton, a sister of that eminent Biblical scholar, Prof. Andrews Norton of Harvard College.

From his earliest childhood Edward Wigglesworth manifested those fine traits and virtues of character, and that love of the processes of thought and the acquisition of learning, which were so marked in him through his whole life. Having been prepared for college by the Rev. Ebenezer Pemberton of Boston, he completed his course there in 1822, graduating with the highest honors of his class. He pursued the study of the law in the office of the late Judge William Prescott, having there, as fellow-students, the late Franklin Dexter, and the late Nathaniel I. Bowditch. Though he began the practice of the profession, it did not prove to be congenial or attractive to him, and he abandoned it to enter his father's counting-room, to aid him in his mercantile affairs.

Those who at the time or in later years had a personal and intimate acquaintance with Mr. Wigglesworth, and were thus appreciative of the high and almost morbid conscientiousness, and of the even excessive tenderness of sympathy and benevolence, which were so marked in his character, can answer only with an assenting smile when told that he was not, either as a lawyer or a merchant, an effective agent in the collection of even the most honest debts. When put upon such errands his frequent report was that the creditors seemed so much in need, or so reluctant to pay, that he shrank from using any urgency, and so came back empty. Still, he was of service to his father in his business affairs, though he never engaged in such interests with partners or by himself. He acquired sufficient practical knowledge for the care of a paternal estate, his share in which made him affluent. Intellectual and scholarly culture, with the oversight and administration of a large number of charitable, benevolent, and humane societies, divided in about equal measure the whole half-century of Mr. Wigglesworth's mature life. He was a diligent reader and student, and acquired a large amount of varied knowledge, which he aimed to have accurate and thorough. When, in 1829, that learned and laborious German scholar, Dr. Francis Lieber, who had become naturalized among us, undertook to translate, and to adapt to the uses of American readers, the voluminous Encyclopædia published by Brockhaus, of Leipsic, under the title of "Allgemeine deutsche Real-Encyklopædie (Conversations-Lexicon)," he found it necessary to have efficient helpers. The enterprise was for its time, a very serious and important one, having been preceded in that form of literature here only by the republication of the London edition of Dr. Rees' Cyclopædia. Dr. Lieber was so fortunate as to secure the ready and competent co-operation of Mr. Wigglesworth, as his foremost helper. In the preface to the work, in thirteen volumes, published under the title of the "Encyclopædia Americana," Dr. Lieber makes the following recognition of the aid which he had received: "Above all, I ought to acknowledge the zealous and able co-operation of my friend and associate, Mr. Wigglesworth, who will not permit me here to express my obligations to him in such terms as my feelings would dictate. With him I shall be happy to share whatever approbation the public may think the work shall deserve."

If Mr. Wigglesworth had been prompted to devote his years of easy leisure to the examination and exposition of some single subject in science or literature, that he might prove his claims as an author, he would undoubtedly have produced one or more works that would have

secured for him approval, reputation, and fame. Such productions from his pen as came into print are simply fragmentary, mostly in the form of brief sententious "Reflections," having the point and force of clear moralizing and cast into the compressed shape of proverbs. He had a sagacious discernment, a fertility of imagination, and a vivacity and sparkle of wit and humor, running with equal facility into prose or verse, which, however, he indulged in fulness only in the festive enjoyments of a large and happy family circle.

Intervals of impaired health, making journeys and travels in this country and in Europe occasionally necessary for restoration, and a general susceptibility to some depressive moods, — no doubt aggravated by his constant and faithful service in agencies of ministration to the sorrows and ills of humanity, — seemed at times to cloud the spirit of Mr. Wigglesworth. His modesty, diffidence, and self-depreciation, his purity of heart, his gentleness of spirit, and the fulness and generosity of his benevolent sympathies, drew to him the most tender attachment of his family and his connections, and the profoundest respect and regard of the whole community in which he was known. His name, with a generous sum attached to it, appeared in answer to all such appeals as made necessary the announcement of subscriptions for the purpose of drawing others; but there was no record, public or private, of his daily alms or of the secret channels of his generosity. The religious sentiment was deep and strong in him through life, and it was the most potent element in the training and influence of his character.

For more than thirty years, Mr. Wigglesworth gave of his means, his time, and his warm interest, most efficient service to that foremost of the benevolent institutions of this city, "the Massachusetts General Hospital;" having been through the whole of this period a member of its corporation, as one of its trustees, or vice-president, or president. He was also an officer of the first and best administered of the now numerous corporations for similar purposes among us, "The Provident Institution for Savings in the Town of Boston." In the discharge of this responsible trust, he engaged with a constant and patient diligence and fidelity, examining investments and securities as if he were himself the guardian of the frugal savings of each of the depositors. He took entire charge of two of the City Districts of the Boston Provident Association, and for years supported them from his own resources, making no draught whatever upon the funds of the Association. Most of the other numerous charitable institutions of the city, and very many of its literary and religious enterprises found in him a wise and just administrator, and a generous patron. There are many of his associ-

ates in one or more of these multiplied fellowships who will long cherish in love and respect the memory of this upright, kind-hearted, and thoroughly good man, as he came with his modest presence to business meetings, sitting for the most part in silence, but ready always, when his word and opinion were needed, to utter them with a calm wisdom and a gentle earnestness.

ALEXIS CASWELL.

ON the 8th of January, 1877, Rhode Island lost, by death, an accomplished man of science, and one of her best citizens. Alexis Caswell was born in Taunton, Mass., on the 29th of January, 1799. His ancestors, on the father's side, were prosperous farmers, and were among the earliest settlers of Taunton. Thomas Caswell, of the fifth generation preceding, came, according to tradition, from Somersetshire, England. His will was admitted to probate in 1697; only fifty-eight years after the incorporation of Taunton. The grandfather of Alexis married Zibiah White, who was the great-granddaughter of Peregrine White, the first born of the Pilgrims in America on board the Mayflower, November, 1620. Alexis Caswell, after spending his early years upon the farm, was prepared for college at the Bristol Academy in Taunton. Little is known of his character and attainments at this time; but, if the child is father of the man, he must have been amiable, docile, and full of a high ambition. At the age of nineteen he entered Brown University, over which Dr. Messer then presided. His course in college was eminently successful; and, at his graduation, in 1822, he received the first honors.

From 1822 to 1827, he was connected with Columbian College, Washington, D. C., as tutor or professor of languages; at the same time studying theology under Dr. Staughton, the President. In the autumn of 1827, he went with Dr. Irah Chase (professor in the Newton Theological Seminary from 1825 to 1843), to Halifax for the purpose of establishing the Granville Baptist Church in that place. His plans were changed, in consequence of an invitation which he received from the people to remain among them. He was ordained on the 7th of October, and settled over them as their pastor. Having preached to them acceptably for a year, he received an invitation from the first Baptist Church in Providence in the summer of 1828 to assist the Rev. S. Gano, the pastor of that church. He had been in Providence only a few weeks, when he was appointed Professor of Mathematics and Natural Philosophy in Brown University. With the

exception of the time when he visited Europe, in 1860–61, he discharged the laborious duties of this office for thirty-five years, to the complete satisfaction of the government and the pupils of the institution. Engaging in its instruction soon after Dr. Wayland's accession to the presidency, he was his strong support throughout an able and vigorous administration. In many respects, one was the fitting complement of the other, and respect and confidence were felt equally on each side. In 1840, while Dr. Wayland was absent in Europe, Professor Caswell discharged the duties of President; and, during the last three years of President Wayland's official term, Professor Caswell, under the title of Regent, relieved him from all the anxieties of discipline, bringing to this delicate duty qualities of mind and heart which secured good order without alienating the affection of the students.

When Dr. Caswell resigned his professorship in 1863, he was sixty-four years of age; and had fairly earned the leisure and the retirement which are the reward and the luxury of old age. But he was still young in the best sense of the word; young in his feelings, in his habits of industry, in his intellectual faculties, in the good constitution which he had inherited from his father (who died in 1851 at the advanced age of ninety-one), and young in his passion to serve his day and generation to the end. Accordingly, he engaged in active affairs with a vigor and success which younger men might well have envied. Refreshed by five years, not of repose, but of a change in his intellectual diet, he again obeyed the voice of his Alma Mater, which called him, in 1868, to the Presidency of Brown University; Dr. Sears, his predecessor, having been summoned to an urgent and difficult service by the strong voice of patriotism and humanity. Although Dr. Caswell had been moving for a few years outside of the University domain, his heart was always there. He knew, better probably than any one else, the wants, the resources, and the aims of the institution; and, notwithstanding that he stood on the brink of threescore years and ten, he brought to his high position the vigor, the freshness, and the hope of youth. Among the various needs of the University which he pressed upon the attention of the corporation, in his annual reports, was the establishment of an astronomical observatory, sufficient for the purposes of instruction if not of research.

Soon after leaving the office of president, in 1872, Dr. Caswell was elected into the Board of Trustees, and, in 1875, he was chosen a Fellow of the Corporation. In 1841, he received the degree of D.D., and, in 1865, that of LL.D.; both from his own university. For nearly fifty years, he had been associated with it, either as student,

teacher, president, trustee, or fellow: and in each and all of these relations he had reflected back all the honors which he had received as a favorite son. Earnest, devoted, and generous himself, he had the power and the disposition to enlist others, of larger means, in the same cause. None of its distinguished children has exceeded him, perhaps none has equalled him, in length of service and fidelity to its sacred trusts.

The special function and the high delight of Dr. Caswell were those of an educator. When he began his profession of teacher, he shared the fate of his contemporaries in older and richer universities in a new country. He was responsible for all the instruction given in mathematics and natural philosophy; in fact, he alone represented the scientific side of the institution to which he was attached. Afterwards, a professor of chemistry, and at a much later period professors of natural philosophy or mathematics, were associated with him; so that, in 1850, his own duties were restricted to astronomy, from 1851 to 1855 to mathematics and astronomy, and after 1855 to natural philosophy and astronomy. It could not be expected of any man who was required to scatter his energies over a variety of subjects, which in a well appointed university would tax the best efforts of half a dozen professors, that he should have much leisure or disposition for original investigation in one direction. It was enough, and more than enough, for the most laborious and ambitious teacher that he should maintain a high standard of scholarship in the wide field which circumstances forced him to cultivate. Much has been written during the last few years in regard to the endowment of scientific research. But this is a luxury of which no one dreamed in Dr. Caswell's day; and its strongest advocates at the present time are not in agreement as to the best way of accomplishing the desirable result. Mr. Huxley may be correct in his opinion that a moderate amount of teaching will not check but stimulate the zeal of the original explorer. But no one will think that a mind, wearied by excessive teaching, distracted by a multiplicity of topics, and prevented from rising in his instruction to the Alpine heights of science by the dulness or indifference of the average student who despairs even of reaching the table-land, is a congenial soil for advancing human knowledge. Under such circumstances, one of two things must happen, — either the work of teaching will be neglected, or that of original research will be left to men more favorably placed.

It must not be inferred from these remarks that Dr. Caswell was contented to remain stationary. At no time, since his scientific life

began, has it been an easy task even to keep in sight the few who are steadily advancing the outposts of science; and, of late, it is quite impossible without concentration. Dr. Caswell's predilection was for meteorology and astronomy. During the long period of twenty-eight and a half years (from December, 1831, to May, 1860), he made, with few interruptions, a regular series of meteorological observations, at the same spot on College Hill, in Providence. These observations, precise as regards temperature and pressure, and including also much information on winds, clouds, moisture, rain, storms, the aurora, &c., have been published in detail in Volume XII. of the "Smithsonian Contributions to Knowledge," and fill 179 quarto pages.

In 1858, Dr. Caswell delivered four lectures on astronomy at the Smithsonian Institution in Washington. They were of the highest order of popular instruction, and, on that account, were thought by Professor Henry worthy of being permanently preserved in his printed report for that year. Whatever may have been, or may still be, the conflict between science and theology, there is no conflict between science and religion; least of all in Dr. Caswell's mind. He says in his introductory remarks: "The mechanism of the heavens, in proportion as we comprehend more and more of its vastness and seeming complexity, bears witness to the enduring order and harmony of the universe, and points with unerring certainty to the superintending agency of an intelligent and infinite Creator." And again: "We spontaneously pay the tribute of our homage to all great achievements. But in no case is homage more just or more enduring than that which all cultivated minds pay to him who stands as the minister and interpreter of Nature, and makes known to us her laws and her mysteries. Many such adorn the annals of astronomy."

Dr. Caswell joined the American Association for the Advancement of Science at its second meeting, which was held at Cambridge in 1850. Although he made no formal contribution to its proceedings, he was a frequent attendant upon the annual meetings, took part in the discussions, and always gave dignity to its deliberations by his character and his words. In 1855, the Association had its ninth meeting in Providence; and the hospitable reception then given to it, and the hearty appreciation felt for its labors, were largely due to his influence. The members expressed their gratitude for this service by electing him as the vice-president for the next meeting, in Montreal. But the death of the President elect, Professor J. W. Bailey of West Point, called Dr. Caswell to the chair. At this large representation of the science of the Continent (the only meeting which has taken place

outside of the limits of the United States), he sustained the credit of his country on a foreign soil, by his dignified presence and his manly eloquence, to the great satisfaction of all his associates. At such a time and in such a position, Dr. Caswell appeared to great advantage. By his dignity, his address, and his courtesy he was eminently qualified to be a presiding officer; and he was gifted with a fluency, a felicity, and a weight of speech which rose to the requirements of the occasion. At the next meeting of the Association in Baltimore, the president and vice-president elect were absent, and every hand was uplifted in favor of placing Dr. Caswell again in the chair. Having been called to preside over two of the most brilliant gatherings of this scientific body, he was expected to discharge the last duty of a retiring president by giving the address at Springfield. After showing that science had an intellectual value far transcending its practical use, he discussed the objects, the opportunities, and the hopes of science in America; drawing his illustrations chiefly from astronomy, partly because it was his favorite study, and partly because it had the start of all others in material resources. In this excellent address, admirable in thought, spirit, and style, Dr. Caswell reiterates his conviction that genuine science is not unfriendly to religion. "We participate in no such fear. We wish explicitly to exonerate this Association from all suspicion of undermining, or in any manner weakening, the foundations of that faith which an apostle says was once delivered to the saints. We cannot admit the opinion that any progress in science will ever operate to the disparagement of that devout homage which we all owe to Him in whose hand our breath is, and whose are all our ways. Science, on the contrary, lends its sanction and adds the weight of its authority to the sublime teachings of revelation."

In this connection, two other scientific publications of Dr. Caswell may be mentioned: I. On Zinc as a covering for building; "American Journal of Science," 1837. II. Review of Nichol's Architecture of the Heavens; "Christian Review," 1841. Dr. Caswell was elected an Associate Fellow of this Academy in 1850. He was one of the original members of the National Academy of Sciences. He wrote a Memoir of that worthy pioneer in American Science, Benjamin Silliman, which has been printed in one of its volumes of Proceedings.

In this retrospect of the life and labors of Dr. Caswell, he has been seen almost exclusively in his professional relations, as the student and teacher of science. And here his mind took more delight in ranging over a wide field than in dissecting some single flower or tracing the path of a solitary molecule, although that may be a microcosm in

itself. He could not have become one of Berkeley's minute philosophers. He was no specialist, though he was never superficial. If he was not himself an original discoverer, he understood and admired the discoveries of others, and led others to do likewise. At one time he taught Butler's Analogy at the university, and with as fresh an enthusiasm as if that alone had been the chosen work of his life. And wherever there was a gap in the means of instruction, he was the person thought to be fitted to fill it. His whole nature revolted at the suggestion of becoming a bookworm or a secluded student. He was emphatically a man of the world, though not of it. He was interested in trade, manufactures, and finance. He was a good citizen, and took an active part in promoting the industrial, intellectual, and moral welfare of his city, his State, and the whole country. His sympathies were deep and generous. Always welcomed in the circles of the refined and educated, he will be no less missed in the homes of the poor and the unfortunate. His heart and mind and strength were liberally expended in the administration of the public charities of the city and State.

Dr. Caswell was an earnest speaker, and a clear, warm, and vigorous writer. To his publications, already mentioned, may be added: I. *Φ B K* oration in 1835. II. Review of Whewell's Bridgewater Treatise; "Christian Review," 1836. III. Article on Emulation; "North American Review," 1836. IV. Address at the funeral of Rev. J. N. Granger, 1857. V. Memoir of John Barstow. VI. Sermon on the Life and Christian work of Dr. Francis Wayland.

Truly was it said of Dr. Caswell, at his funeral, that nature did much for him, but that grace had done even more. Firm and earnest in his own religious convictions, inflexible in his own peculiar theology, he had no taint of illiberality in his intellect or his heart; ever abounding in that Christian charity which thinketh no evil of any who conscientiously worshipped the same God from a different altar. He had mingled in the affairs of practical life more than usually happens to an academic career, but the purity, the integrity, and the simplicity of his character were superior to its surroundings; and, to the end, he seemed as much in place in the pulpit as if he had never left the profession of his early choice. There was no austerity in his goodness; hence it attracted those who could not have been driven. Sweet in temper, cheerful in disposition, gentle, affectionate, affable, hospitable, he was happy in his life, and even more happy in his death. After his long day, in which he had not labored in vain, his sun went suddenly down in a cloudless sky. And behold the end of such a man: it is all

honor, and affection, and peace. The press, the university, the church, and the State, have borne witness to the excellence of his character and the usefulness of his life.

CHARLES HENRY DAVIS.

Charles Henry Davis was born in Boston, 16th January, 1807. His father was the Hon. Daniel Davis, a lawyer of distinction, and long the Solicitor-General of Massachusetts. His mother was born Margaret Freeman, sister to the Rev. James Freeman, the eminent minister of the King's Chapel. He was admitted to Harvard College in 1821; but left it two years later, to enter the naval profession. In 1841, however, the university conferred on him the degrees of A.B. and A.M., and, in 1868, that of LL.D., and his name stands in the triennial catalogue in the list of members of the class of 1825.

His commission as midshipman bore date 12th August, 1823. For some fifteen or twenty years after this time, his life was occupied with the duties and pleasures of his profession. He became passed midshipman in 1829, and lieutenant in 1834. His ever distinct personality outwardly displayed itself chiefly in the gayety, the spirit, and the physical energy of youth. But the activity of nature which thus found its expression was in reality the outgrowth of the vigor and brilliancy of his mind and character; and these qualities were all the time gaining maturity and tempered strength in reading, reflection, and intercourse with the world. His habits of thought and feeling bore ever after deep and pleasant traces of the education of those earlier years.

About 1840, Lieutenant Davis took up his residence in Cambridge, and undertook a serious course of reading and study, especially in mathematics, which he pursued under the guidance of Professor Peirce. In 1842, he was ordered to duty on the Coast Survey, of which Professor Bache was the next year appointed superintendent; and he continued as one of the most valued officers in this service till 1849. The department to which he was primarily assigned was the investigation of the velocity and direction of the tides and currents in New York Harbor, in the Gulf Stream, and in the neighborhood of Nantucket; and the efficiency and ability which he displayed in this work led to his frequent appointment on commissions, both then and subsequently, to examine the principal harbors of the country. These researches engaged him in the general study of the laws of tidal action, in which he made valuable additions to knowledge, and was led to the adoption of new and striking views, embodied in his "Memoir upon

the Geological Action of the Tidal and other Currents of the Ocean" (Mem. Am. Acad., new series, vol. iv.) and his "Law of Deposit of the Flood Tide" (Smithsonian Contributions, vol. iii.). The object of these publications, which made him known to men of science as an hydrographer of the highest learning and skill, was to exhibit the law of connection between the currents of the sea and the alluvial deposits on its borders and in its depths, and to show that this law had contributed in past ages, in an important degree, and was still constantly contributing, to the determination and modification of the forms of the continents.

At the same time with the performance of this valuable scientific work, he was rendering conspicuous services to the country, by labors of more directly practical utility. His discovery, in the successive years from 1846 to 1849, of a series of important shoals, before utterly unsuspected, lying in one of the most constantly traversed regions of the ocean, directly in the track of vessels sailing between New York and Europe, or between Boston and West Indian or Southern ports, attracted public attention very powerfully to the value of the Coast Survey, which had not then acquired the position it now holds in the confidence of the country. Several considerable wrecks and accidents, before unexplained, were accounted for by these discoveries, which called forth special letters of acknowledgment from merchants and insurance companies.

Lieutenant Davis was detached from the Coast Survey in 1849, and ordered to duty as the first superintendent of the new "American Ephemeris and Nautical Almanac," which owed its foundation directly to his efforts. The following extract from a letter of Professor Bache to the Secretary of the Treasury, dated 17th July, 1849, — a letter in no way called for by any courtesy of custom, — shows the estimation in which he was held by his eminent chief: "The official reports of the progress of the Coast Survey have, from time to time, brought the name and services of Lieutenant Davis very prominently before the department, as marked by all the qualities which insure distinction in such a work. The loss of his services will be deeply felt. The zeal, industry, knowledge, and judgment ripened by experience, which he has brought to the survey, cannot soon be replaced. They have conferred upon it some of its most decided claims to usefulness and public approval. In parting with this most valued officer for a field of duty alike honorable to him and useful to the country, I desire to place on the records of the Treasury Department the strongest expression of my sense of his merits in the career which he leaves."

But while the labors of our deceased associate in the hydrographic work of the Coast Survey established his reputation as an accomplished and able investigator, and were of high public value, he rendered still more important benefits to his country and to science by his successful organization and conduct of the "American Ephemeris." The establishment of this work was urged by its projectors, and especially by Lieutenant Davis (the prime mover in the undertaking), with two motives: first, to advance the scientific character and standing of the country, by a publication of the highest order from a scientific point of view; and, secondly, to promote the cause of astronomy itself, and render substantial services to navigation, by producing a work on a higher plane than the "British Nautical Almanac," fully conformed to the latest developments of knowledge, and likely to give an additional stimulus to pure research. To carry out this ambitious plan, with the revision of the solar, lunar, and planetary tables, and of various points of astronomical theory, which it involved, it was necessary to enlist in the work the ablest mathematical astronomers of the country, and at the same time to train up a body of young computers, and to inspire them not only with the spirit of numerical accuracy, but with the true love of science and desire to advance it. To this arduous but most interesting task, Davis brought his admirable judgment and his fine scientific talents, together with that fortunate temperament which easily united various men in loyalty to one enterprise, and that generosity of nature which thought only of doing the work in the best manner, and gladly gave the freest possible play to others' individuality. The first volume of the "Ephemeris" appeared in 1852, and was very favorably received on both sides of the Atlantic; and it may be safely said, that, except the Coast Survey, of which the vast scope of course gives it pre-eminence, no scientific work which has been carried on in this country has redounded more largely to the national credit. "The policy adopted in the newly formed office," writes one who was familiar with it, and whose judgment is authoritative, "though not in all respects to be permanently imitated as a piece of administrative machinery, was such as to make it a more efficient promoter of mathematical astronomy in this country than any organization we have ever had. Young men of talent were looked for from all quarters, were employed without regard to personal or political influence, were paid according to their efficiency, and were encouraged to engage in any branch of mathematical or astronomical research which would tend to improve the almanac. In the work of the office there was a freedom from discipline and restraint, which, though it might work badly under other circumstances, was

very favorable to the development of a school of mathematicians. Besides men like Peirce and Walker, who had attained eminence before becoming connected with his office, the names of President Runkle, Professors Winlock and Newcomb, Chauncey Wright, and William Ferrel, may be cited as representatives of the men who were first brought out through their connection with the Nautical Almanac."

In 1854, Davis attained the rank of commander; and, in 1857, he published an English translation of Gauss's "Theoria Motûs Corporum Cœlestium." The period of his superintendency of the almanac was interrupted by a three years' cruise in the Pacific Ocean. This cruise was signalized by a striking exhibition of the decision of character and willingness to assume responsibility for which he was ever noted in the service, in his acceptance, in the name of the United States, of the surrender of Walker in Nicaragua, — a step which saved many lives, and prevented serious complications, and which Davis took without any explicit instructions from the commander-in-chief of the squadron.

In 1861, soon after the outbreak of the civil war, Davis was made a member of a board of officers assembled at Washington to inquire into and report upon the condition of the Southern coast, with a view to offensive operations on the part of the United States. This inquiry led to the organization of the squadron which was placed under the command of Flag-Officer Dupont, and of which Davis was appointed fleet-captain and chief-of-staff, and to the capture of Port Royal, — the first brilliant naval achievement of the war. Davis was prominently engaged in both the planning and the execution of this magnificent action; in which two strong forts, splendidly manned, and mounting forty-three guns, nearly all of heavy calibre, yielded in four hours to an attack as beautiful as it was able, and one of the largest and noblest harbors of the South, — indeed, one of the finest in the world, — with all the surrounding country, fell into the hands of the Federal Government. In Flag-Officer Dupont's official report of 11th November, 1861, he says of Commander Davis: "In the organization of our large fleet before sailing, and in the preparation and systematic arrangement of the details of our contemplated work, — in short, in all the duties pertaining to the flag-officer, — I received his most valuable assistance. He possesses the rare quality of being a man of science and a practical officer, keeping the love of science subordinate to the regular duties of his profession. During the action, he watched over the movements of the fleet, kept the official minutes, and evinced

that calmness in danger, which, to my knowledge for thirty years, has been a conspicuous trait in his character."

In May, 1862, Davis (now captain) was appointed flag-officer of the Mississippi flotilla off Fort Pillow; and, one or two days after assuming command, he with seven vessels beat off a squadron of eight iron-clads which had steamed up the river and attacked him. The action was a spirited one, and lasted nearly an hour. Three of the hostile gunboats were disabled, but avoided capture by taking refuge under the guns of the fort. On the 5th of June Fort Pillow was abandoned by the Confederates, and on the sixth Davis fell in with their ironclads and rams, opposite Memphis. A running fight ensued, resulting in the capture or destruction of all the Confederate vessels but one, and the surrender of Memphis. Davis then joined Farragut, and was engaged in various operations near Vicksburg, and in the Yazoo River.

In this year, the Bureau of Navigation was established, and Davis was appointed its first chief. In 1863, he received the thanks of Congress, — a distinction which entitled him to ten years of active service beyond the regular time of retirement, — and was promoted to the rank of rear-admiral. Two years later, he became superintendent of the Naval Observatory at Washington. In 1866, in compliance with a resolution of the Senate, he prepared a valuable "Report on Interoceanic Railroads and Canals," which was revised and reprinted in 1870, and furnished by the Navy Department to Captain Selfridge for his instruction in making his surveys. In 1867, he was again ordered to sea, in command of the South Atlantic Squadron cruising in South American waters.

In 1868, while Admiral Davis was in command of this squadron, he became the object of a bitter personal attack, in consequence of his not acceding to the views of the United States Ministers in Paraguay and Brazil as to his proper action in relation to the troubles then agitating the former country. Into matters of controversy this is not the place to enter; but our notice would be incomplete without a brief recital of the facts of the case. A state of war existed in Paraguay, then subject to the dictatorship of Lopez; and our minister, deeming his position insecure, withdrew from the country, leaving behind him two citizens of the United States, who were arrested and imprisoned, at the moment of his departure, on the charge of conspiracy against the Paraguayan government. Admiral Davis was accused of delay in demanding the release of these prisoners, and of accepting their surrender, when it was made, after a parley with Lopez and under conditions. In fact, the

charge of delay arose from his declining to consider his squadron as under the orders of the diplomatic authorities: he acted with as much promptitude as he conceived to be consistent with his duty of making sure of his ground in a much-debated case; and the men were given up on a peremptory summons, accompanied by a proper display of force, and under no conditions. His line of conduct was thus completely successful: and it was fully sustained by the State and Navy Departments. But a vote of censure was passed by the House of Representatives, under the influence of the hostility which had been excited in certain quarters by his independent course. The moral weight to be attached to this vote may be estimated from the circumstance, that it joined in the same condemnation Admiral Godon, whose action had been dictated by the explicit orders of the Secretary of the Navy. His reputation suffered nothing among those who fully understood the merits of the case. The affair was, in truth, a conspicuous instance of the decision of character, the soundness and reasonableness of judgment, the conscientious and noble-minded patriotism, and the high sense of professional responsibility, which always distinguished him.

Admiral Davis returned from his South American cruise in 1869, and was for several years in command of the Navy Yard at Norfolk. In the winter of 1873-74, he was again appointed to the superintendency of the Naval Observatory, in time to take an active part in completing the preparations for the expedition to observe the transit of Venus. In the session of 1874-75, Congress made an appropriation for printing illustrations of the results of the Polaris Expedition to the Arctic regions, commanded by the late Captain C. F. Hall. The Secretary of the Navy requested Admiral Davis to prepare the work and take charge of its publication; and this labor formed the principal occupation of the last two years of his life. He threw into it an interest which seemed to deepen at last with every chapter; giving assiduous attention to the least details of the narrative, and bringing to bear on it all the additional illustrations he could anywhere gather of the character and purposes of the commander and other officers of the expedition. The work, which was nearly completed under his hand, is early expected; and it is believed that it will be fouud fully worthy of its connection with his name.

For several years his health has somewhat declined. But he worked regularly on the proofs of the Polaris narrative till the fourth day before his death, when he had to abandon the effort and go to bed. From that time he failed very rapidly, but without suffering, and died early in the morning of Sunday, 18th February, 1877.

"Notwithstanding the active and prominent life which Admiral Davis led, and his energy and dash as a naval commander," says one whose words have been already cited, "his tastes, especially in his later years, were much more those of the refined gentleman of literary leisure than of the active man of the world. He was little inclined to mingle in general society, but rather sought that of the cultivated few whose tastes were congenial with his own. His relations with the men of science who were his official subordinates were singularly free from those complaints, jealousies, and distrusts which so often arise when military men are placed in charge of works of a purely scientific character. This arose from an entire absence of every trace of jealousy in his nature, combined with an admiration of intellectual superiority in others, which led him to concede every thing to it. He combined independence of character with Christian courtesy, in a way that made him a model to the young men by whom he was surrounded. No human being who ever came into his presence was too lowly to be addressed with the most kindly courtesy; and, when arrogance or impertinence became insufferable, no respect for position or influence gloved the hand which dealt the blow."

"His conversation was forcible, full of good sense, and most amusing," says another writer. "He brought to bear on any subject he took up a host of argument, illustration, and elucidation; and he liked to brighten up the dryest discussion of professional and scientific matters with his original and vivid turns of expression, or with some apt and unhackneyed quotation. . . . He was an admirable officer. He had the true spirit of command, — strong, dignified, and quiet; and one that, not needing artificial support, was accompanied by a thoroughly friendly relation to his officers and men. . . . But that which is felt most deeply now by those who knew Admiral Davis well is the loss of a man of rare and noble character. He was a charming companion, abounding to the last in a natural freshness and gayety of spirit; and he had one of the most honorable, upright, true, generous, and gentle hearts that ever beat. He was a man of marked courage, and had, eminently, the courage of his convictions. At the same time, he was distinguished by perfect courtesy, having but one standard of manners — and that a finished, but unaffected standard — for all classes of men. . . . He bore good-will to every one, and was always in a cordial vein. Meanness, trickery, and malice, indeed, roused his bitter contempt. But a salient characteristic of at least his later years was his profound trust in human nature, his complete freedom from cyni-

cism, and his faith in the power of right and truth to conquer both the world and the individual conscience. He

> "'Still in his right hand carried gentle peace
> To silence envious tongues.'

. . . We may say of him, as it was said of Sir Launcelot, he was 'the kindest man that ever struck with sword.'"

CHARLES DAVIES.

ON the 18th of September died Professor CHARLES DAVIES, of Fishkill, on the Hudson. His family was of Welch origin, settled in Washington, Litchfield County, Connecticut. Born in 1797, he was removed with his father and his family to St. Lawrence County, New York, in the early part of this century. That region was then almost a wilderness, on the northern frontier. There he was a farmer's boy, inured to work, to country habits, and to some measure of hardship. With a strong constitution, quick mind, and impulsive character, he had all the elements which were necessary to sustain those habits of study and labor which made him a successful student and a most useful teacher. In December, 1813, he was appointed a Cadet at West Point. In consequence of the rapid promotions (it then being war time), he was promoted Second Lieutenant of Artillery in December, 1815. He was only one year in the army proper, except being paymaster at West Point from 1841 to 1846. In December, 1816, he was appointed Assistant Professor of Mathematics at the Military Academy, — a civil officer, created by law for the purpose of having permanent teachers. In 1821, he was appointed Assistant Professor of Natural and Experimental Philosophy; and in May, 1823, Professor of Mathematics. In this chair he remained until May, 1837, when he resigned, and removed to Hartford, Connecticut, chiefly with a view of preparing and publishing the series of educational works which have since made him so well known. The office of teacher had, however, become habitual and natural to him. He loved it, and so he continued in it almost to the last years of his life. From 1839 to 1841, he was Professor of Mathematics in Trinity College, Hartford. Removing to West Point as paymaster, and subsequently to Fishkill on the Hudson, he was appointed Professor of Mathematics and Philosophy in the University of New York, in 1848, and Professor of the Higher Mathematics in Columbia College, New York, in 1857. There he remained until 1865, when he retired, and was elected Emeritus Professor. Even then he did not cease wholly his connection with teachers and teach-

ing. He was invited to and often attended the Teachers' Associations and meetings throughout the country. In 1844, he was President of the Teachers' Association of New York; and in recent years, a member of the "University Convocation" of New York. It was to that body that he made his Report on the "Metric System," which was published in 1870. In 1824, the degree of A.M. was conferred by the College of New Jersey (Princeton); and in 1825, the same degree, by Williams College, Massachusetts; and in 1840, the degree of LL.D., by Geneva College, New York. If his was a life of actual teaching, it was perhaps still more so as the writer of text-books, and the author of methods. He began with the translation of Legendre's Geometry. It was a capital book on that subject; and its success induced him to go on with other works. Among them are no less than six different grades of Arithmetics; Elementary works on Algebra, Geometry, Trigonometry, Practical Mathematics, Surveying and Navigation, Analytical Geometry, Differential and Integral Calculus, Descriptive Geometry, Shades, Shadows and Perspective. In addition to these, he wrote the Logic and Utility of Mathematics; and, jointly with Professor Peck, the Mathematical Dictionary. The following is a complete list: Primary Arithmetic, Intellectual Arithmetic, First Lessons in Arithmetic, Elements of Written Arithmetic, Old School Arithmetic, School Arithmetic, Practical Arithmetic, University Arithmetic, Elementary Algebra, New Elementary Algebra, University Algebra, Bourdon's Algebra, Elements of Geometry and Trigonometry, Legendre's Geometry, Practical Mathematics and Mensuration, Elements of Surveying, Elements of Calculus, Analytical Geometry and Calculus, Descriptive Geometry, Shades, Shadows and Perspective, Foundations of Mathematical Science, Grammar of Arithmetic, Outlines of Mathematics, Mathematical Tables, The Metric System, Logic and Utility of Mathematics, Mathematical Dictionary.

FIELDING BRADFORD MEEK.

FIELDING BRADFORD MEEK was born in Madison, Ind., on Dec. 10, 1817, and died in Washington on Dec. 21, 1876. The circumstances of his little-eventful life are of small interest to his fellow-workers in science, save in so far as they show the conditions under which his peculiarly acute perceptions and admirable judgment became fitted for his excellent scientific work. Born in a community where science had no place, and urged by his surroundings to begin commercial ventures in a frontier society, with little preliminary training of any sort, and

with seemingly no inherited instincts leading towards a scientific care we yet find him, after one or two unfortunate essays in business, whi deprived him of a small patrimony, taking to the study of nature as l an instinct. Such inquiries as the writer of this notice has been ab to make of his lamented fellow-worker, in their infrequent meeting and of his narrow circle of early intimate friends, have failed to sho in any clear way the steps which led to his beginnings in scienc Much is, perhaps, to be attributed to the fact that his birthplace an the scene of his last work was in the midst of a region richly stor with fossil remains of an extinct and peculiar life; remains that are s captivating in their very strangeness that they cannot fail to gain th attention of eyes not sealed to the great problems of the earth. Hi body, naturally weak, — for he inherited a malady of the lungs tha made his life a long struggle with disease, — may have helped him t that isolation of interests which readily drives a mind of acute perceptions into studious ways.

It is no part of the purpose of this notice to consider his altogethe admirable personal life, — that must be left to other and fitter hands; but there is yet another circumstance of his labor which will interest all those who are concerned with the question of the circumstances that have surrounded those who have done great work in science: for the greater part of his life, our late comrade was cut off by almost total deafness from all ready contact with the world; for all the later and most studious years he was absolutely deaf to every sound. Yet it should be told, as a part of his excellence, that this imprisonment within himself never lessened his beautiful kindliness of spirit, nor checked his ready sympathy with the life about him.

It is Mr. Meek's palæontological labors which will remain his fittest claim to the gratitude of scientific men. Extending, as they do, over a long term of years, and concerning materials from all parts of the geological section, it is difficult to give them any general characterization. To them all may be given the highest praise for painstaking labor and perfect honesty of purpose. They nearly all belong to that class of works which are done in the interests of historical geology, rather than of biology. In this method in which his work was done, he but followed the necessary course of all those who take part in the great work of exploring a region unknown to science, describing facts as they are successively ascertained without much reference to general conclusions. His palæontological work was begun in connection with the surveys of Dr. David Daleman in Iowa, Minnesota, and Wisconsin, in 1848. After the close of these labors, he remained unconnected with any

public work until 1852, when he became an assistant of Mr. James Wall in his great palæontological explorations of New York. From this time to his death he was steadily occupied in that class of governmental researches that forms so large a part of our American scientific work. In the palæontological studies of the surveys in New York, Missouri, Illinois, and Ohio, he had a large share; and in all of them has raised for himself monuments to his painstaking researches. His most important work, however, was done in connection with the government surveys of the Territories. This work was begun as an assistant of Mr. Hall in the study of the then Territory of Nebraska. The principal results of this labor were published by this Academy in Vol. V. of its Memoirs, 1855. The last twenty years of his life he was a resident of Washington, and continually engaged in the study of the rich faunæ of invertebrate life from the districts beyond the Mississippi. His reports on the invertebrate life of these districts, measured by any standard, are to be ranked with the labors of the first palæontologists in the world. The very week of his death, the writer of this notice received the last and greatest of his works, — a report on the invertebrate cretaceous and tertiary fossils of the upper Missouri country, — a quarto volume of between six and seven hundred pages of text and nearly fifty plates. This work alone would prove the fit basis of a great reputation. It shows him to have carried his admirable powers, the unwavering fidelity, the patient courage, which he had borne through forty years of bodily weakness, unshaken to his end.

The peculiar seclusion in which Mr. Meek's life had been passed will not serve to make his loss so quickly felt as that of many another student of nature. But, though he passes from us leaving behind few connected with him by intimate friendships or even close acquaintance, there are few names in the history of American science so sure of a place for the time to come.

ADMIRAL CHARLES WILKES.

THIS distinguished officer entered the navy in 1818, as a midshipman. In 1826, he was made a lieutenant; in 1843, commander; in 1855, captain; in 1862, commodore; and in 1866, rear-admiral. His first cruise was up the Mediterranean; the next on the west coast of South America, under Commodore Stewart. In 1836, he surveyed, in the "Porpoise," George's Bank, off Massachusetts; and, in 1837, Tybee Bar, at the mouth of the Savannah River. In 1838, he was selected by President Van Buren to command the South Sea Exploring Expe-

dition, which sailed from Norfolk, August 19 of that year, and returned to the United States, June 10, 1842. Many valuable contributions to science, geography, and general physics resulted from this expedition. The Antarctic Continent was discovered Jan. 19, 1840; and several islands, reefs, and shoals, before unknown, were placed on the charts. In 1861, he relieved Commodore Dornin on the coast of Africa, and took command of the "San Jacinto;" and with her captured the Rebel commissioners, Mason and Slidell, who were found on board of the British mail-steamer "Trent." In July, 1862, he took command of the James River flotilla, — a large number of vessels, — and served on that station until the Federal troops were removed from Harrison Landing, September of the same year. He was immediately ordered to the command of the flying squadron, and sailed without delay for the West Indies, where his squadron did valuable service, capturing many vessels, until June, 1863, when he was ordered home. This was his last sea service.

At an early age he exhibited a remarkable taste for scientific pursuits, especially astronomy and geodesy. In 1830, he took charge of the Department of Charts and Instruments, at Washington, — a new bureau. Under his supervision, a small observatory (the first) was established at Washington in 1833, when the first astronomical observations, under the auspices of the government, were taken by him, with fixed instruments. In 1835, he erected on his own property, Capitol Hill, a small observatory, which was used by the government for several years. In 1837, he was sent to Europe to purchase instruments for the South Sea Exploring Expedition, then fitting out under command of Commodore Ap Catsby Jones, a duty he was peculiarly fitted for.

Admiral Wilkes was the author of several valuable works. The narrative of the exploring expedition — five large quarto volumes and atlas — was written by him. All the charts of the exploring expedition were constructed under his supervision, comprising two large folio atlases. He wrote the hydrography of the exploring expedition, Vol. XXIII. of the series, — a large quarto volume, — and produced a quarto volume of the meteorological observations made during the voyage, — Vol. XI. of the series of exploring expedition works. He also published works on "Western America," the "Theory of the Winds," "Circulation of the Ocean," and "Zodiacal Light." He was, with others, appointed by the Secretary of the Navy to examine the iron, coal, and timber regions of the Deep River District, N. C., and made an interesting report thereon, which was published by Congress in

1858. The twenty-fourth volume of the results of the exploring expedition, " General Physics," was prepared by him (nearly ready for the press), but was never published, although money was appropriated by Congress for that purpose. It was to contain moon culminations for longitude; transit observations of the sun and stars, for error and rate of astronomical clock; reduced rates of clock or chronometer, by transit of stars, &c., &c.; pendulum observations — not the least valuable those made on Mauna Loa, Hawaii; magnetic observations for variation, dip, and intensity; tides, heights, and a variety of subjects, principally the result of his own observation and experience.

Admiral Wilkes was emphatically a hard worker, never idle; and his efforts in behalf of science were fully appreciated and acknowledged by many learned societies, as were also his nautical achievements. He was made the recipient (1848) of a splendid gold medal, awarded by the Royal Geographical Society of London, in acknowledgment of his discovery of the Antarctic Continent. In 1862, the merchants and citizens of Boston presented him with an elegant sword, and he was complimented with honorary membership in several scientific associations in this country and abroad.

It is worthy of note, that Admiral Wilkes, but a few days after the registering telegraph of Professor Morse was put in operation between Washington and Baltimore, in 1844, by a series of observations, having a well-rated chronometer at each end of the line, determined the difference of longitude between the two cities.

ALEXANDER BRAUN.

Alexander Braun, one of the ablest botanists of our day, died at Berlin, on the 29th of March last, after a short illness. He was born at Ratisbon, May 10, 1805, and therefore had not quite completed his 72d year. In his childhood the family removed to Carlsruhe, where his father took an appointment in the postal service, and at length became postmaster-general of the Grand-Duchy of Baden. Just fifty years ago, Braun was a student at the University of Heidelberg with Agassiz, Carl Schimper, and Engelmann as intimate companions. Our associate, Dr. Engelmann, is now the sole survivor. Braun, Schimper, and Agassiz soon went to Munich, where Oken, Schelling, Döllinger, and Martius (just returned from Brazil) were teaching: but the party, Schimper excepted, was again united at Paris in 1832. The alliance with Agassiz was cemented by the marriage of the latter to Braun's sister.

Braun's predilection for botany must have developed early; for the long series of his communications to the scientific journals began in 1822, when he was only seventeen years old. Upon the completion of his university studies, he became Professor of Botany and Zoölogy in the Polytechnic School at Carlsruhe. He was transferred to the botanical chair at the University of Freiburg in the Breisgau in 1846, accepted a call to that of Giessen in 1850; but in 1851, upon the death of Link and Kunth, he was appointed Professor of Botany and Director of the Botanic Garden at Berlin, where his useful life has just closed. Although the name of Braun is not connected with any discovery of the first order, yet he early took and has well maintained a leading position in the science. He was a botanist of wider culture and acquirement than is now common; but his strength was given to morphology and to the systematic botany of the higher and some of the lower Cryptogamia. His earliest contribution of considerable extent and permanent importance is his memoir upon the arrangement of the scales of pine-cones, published in 1830, which opened the prolific and interesting subject of phyllotaxy. It is understood that the first steps in this direction were taken by Braun's fellow-student, Carl Schimper, who, however, published nothing upon the subject, either then or since: so that, practically, the development of the doctrine was left to Braun, whose memoir is classical. Next to this paper in importance and extent is his memoir on Rejuvenescence in Nature, especially as exemplified in the Life and Development of Plants, which first appeared at Freiburg, in 1859, and then at Leipzig in 1851; and which was reproduced in 1853, in an English translation, by the Ray Society. This, and his paper on the Individual in Plants, which appeared at Berlin in 1852, are writings in which his powers of philosophical generalization as well as of acute observation are strikingly manifested. His systematic work, ranging over a variety of topics, is equally marked by acute insight, close observation, and scrupulous exactness. His investigations of *Marsilia*, *Isoetes*, and their allies, are most complete. Upon the *Characeæ* his first essay bears the date of 1834, and various papers have followed from time to time; but, overtasked by official duties during all his later years, his general work upon the subject has not appeared; yet we may hope that it is left in a condition for posthumous publication. Systematic botanists of ability and experience nowhere abound. In the early part of Braun's career, Germany had its full proportion; but owing to the almost exclusive preference for histology of late years, there are now extremely few, and the loss of a veteran like Alexander Braun will be sadly felt.

CHRISTIAN GOTTFRIED EHRENBERG.

Christian Gottfried Ehrenberg died June 27, 1876, in his eighty-second year. He belonged among the founders of our present zoölogy, and was the first to treat in a scientific way that mass of minute beings formerly included in the vague term "Infusoria." With the synchronism that often marks valuable discoveries, it happened that considerable improvements in the microscope were made about the time he began his favorite investigations, and the demands of his subject led him ever to encourage and aid such improvements.

In 1830 appeared his great work on living infusoria, with admirable plates from his own hand. His interpretation of forms so novel was naturally influenced by previous ideas of organization in the animal kingdom; so that to many of them he attributed organs more or less defined, and a certain complication of structure. As microscopy progressed, these views were modified and corrected by the observers he had trained, or who had been stimulated by his example. The studies of Schwann and Henle on the nature and development of the cell gave a new interpretation to these microscopic creatures. Some were found to be unicellular plants, and others proved the embryos of sponges, and to be even of articulated or radiated animals. But all such corrections were simply the unvarying steps that mark discovery. Ehrenberg it was who took the first step, and who, to the end, remained the master-spirit in this field.

In 1840 appeared his chief work on the fossil infusoria, which exhibited their extraordinary part in building geological formations, whether as a fine sand (Bergmehl), or in more compact forms. He showed that some cretaceous foraminifera are still living, and explained in advance the structure of portions of the deep-sea bottom which have recently been examined by the dredge. The number of these low organisms, figured in his chief works and in his numerous minor publications, is so great as to give data for their geographical and geological distribution over a large portion of the globe.

It must not be thought that Ehrenberg was a specialist of the narrow type which is, unfortunately, so common to-day. He was a man learned in all branches of natural history, and had grown side by side with the science he fostered. Although he spent the greater part of his life in his native Prussia, he travelled a good deal. Having studied at first theology, and afterwards medicine, at Leipzig, he moved, in 1817, to Berlin, and there devoted himself to what proved to be the occupation of his life. From 1820 to 1825, he travelled with Hemprich in Arabia,

Egypt and Nubia, and brought back to his patrons of the Berlin Academy a rich collection. He published from it "The Corals of the Red Sea," a work which gave him a high reputation. In 1829, he went with Humboldt to the Ural Mountains; and, in 1839, he received the appointment of professor in the University of Berlin.

Ehrenberg enjoyed the advantage that originality gives. He helped build up zoölogy, and he created a special department in its study. Thus it was easy for him to keep on the crest of the front wave. All the labors of his followers only added to his power and elevation.

WILHELM FRIEDRICH BENEDICT HOFMEISTER.

WILHELM FRIEDRICH BENEDICT HOFMEISTER, the distinguished vegetable anatomist, and the successor of von Mohl in the chair of Botany at the University of Tübingen, died on the 12th of January last, in the 53d year of his age. He was born at Leipzig, May 18, 1824, where his father was a publisher; and the son entered upon the same profession, devoting, however, his leisure to microscopical research. His first memoir, which established his reputation, viz., that on the formation of the embryo in plants (*Die Entstehung des Embryo der Phanerogamen*), was published at Leipzig in the year 1849. These researches were confined to the monocotyledonous and proper dicotyledonous plants. It was followed, in 1851, by his still more important and elaborate researches upon the development and fructification of the higher Cryptogamia and the Coniferæ; and soon after appeared another memoir upon the Vascular Cryptogamia (*Beiträge zur Kentniss der Gefässkryptogamen*). In 1859 and 1861, he brought out the results of his new investigations upon the formation of the embryo in phanerogamous plants. His minor contributions to the journals of the day are numerous, all relating to vegetable anatomy and development. Called now to the chair of Botany in the University of Heidelberg, he undertook the preparation of a text-book, viz., the *Handbuch der Physiologischen Botanik*, in connection with DeBary, Irmisch, and Sachs; each taking a particular department. Hofmeister published the main anatomical part (*Die Lehre von der Pflanzenzelle*) in 1867, and the morphological (*Allgemeine Morphologie der Gewächse*) in 1868. Since his translation to Tübingen, in the autumn of 1872, only minor papers have appeared, to testify that his wonderful energy was not exhausted. Hofmeister was a worthy successor of Mohl; but the contrast is striking. Mohl published far too little; but all that he wrote was clear and plain. Although the value of Hofmeister's work

may be well proportioned to its amount, and although his earlier writings are not wanting in perspicuity, it is reported that his fellow-laborers among his own countrymen find it difficult to understand his later publications.

CHRISTIAN LASSEN.

Among the many illustrious scholars who have passed away during the last year, none had achieved a higher or more deserved fame than Christian Lassen, of Bonn. He was a native of Norway, born at Bergen almost with the century, or late in 1800; and he died on the 8th of May last. The weakness of age, with a growing infirmity of eyesight, which rendered him during all the last years of his life nearly blind, has withdrawn him for some time from the ranks of the active workers, and given him the aspect of a survivor from a past generation. He belongs, indeed, to the little band of men who inaugurated in Europe the study of India through its own sacred language, the Sanskrit; and he was the last of them yet left in life. It is striking and strange that there should have died so recently one whose activity as a scholar covered the whole history of a branch of knowledge which has assumed such importance and prominence, which has yielded such great results, and become an acknowledged necessity to an education in philology. Lassen was led to take up Sanskrit by the influence of A. W. von Schlegel, under whom he first studied at Bonn, becoming afterwards his collaborator, and his successor. The (incomplete) Râmâyana, the Bhagavadgîtâ, and the Hitopadeça, were the works in whose preparation he took more or less part: the two last of these, especially, are still authoritative, unsurpassed in method and merit of execution. In 1827 appeared his first two works: the celebrated *Essai sur le Pali*, prepared in company with Burnouf, and a geographical and historical dissertation on the Penjab, which was the forerunner of his gigantic *Indische Alterthumskunde*, the principal labor of his life. This began to appear in 1847, and was broken off with the fourth volume in 1861–62, by reason of its author's physical infirmities; although he was still able to produce a second edition of the first two volumes, rewritten and enlarged, in 1867–74. It was the misfortune of this work, meritorious as it is, that it was begun too soon for the results of the Vedic researches to be brought fully into its early portions. The study of India, indeed, was and still is in too inchoate a state to admit of its results being cast into any thing like a permanent form. Apart from those already mentioned, Lassen's principal contributions to this department of learning were an edition of the

Gîtagovinda, with notes and Latin version; part of the drama Mâlatî-Mâdhava; a Sanskrit Anthology, with glossary; and an elaborate Prâkrit grammar: also, a host of important articles in Oriental journals. Of the *Zeitschrift für die Kunde des Morgenlandes* he was long editor and chief author. He by no means, however, confined his studies to India. His aid in the decipherment of the Persian cuneiform inscriptions was very important; and he tried his hand also, with effect, upon the Umbrian. The Zend and modern Persian were subjects included in his University lectures.

Lassen was admirable for singleness and simplicity of character, freedom from affectation or pedantry, and courtesy and helpfulness to his pupils. A contented cheerfulness of disposition, too, was a striking characteristic. Few men have combined a life so splendid in the eyes of the learned world with such narrowness of means and such physical trials. The failing of his eyes, probably brought on by excessive use in difficult collations, began to grow serious after 1840; and it was followed by other weaknesses, which compelled him to spend the greater part of his time reclining on a lounge, and to be wheeled about in a chair. His lectures came to an end in 1864. His last literary work was done by the aid of his wife and of a reader and amanuensis. He lost until the very end neither his memory nor his keen interest for every thing that bore upon the studies of his life. He was married in 1849, and leaves no children.

JOHANN CHRISTIAN POGGENDORFF.

THE story of the noble and useful life of Johann Christian Poggendorff may be told in a few words. He was born at Hamburg, Dec. 29, 1796; received his early education at the Gymnasium in that city; and at the age of sixteen entered the shop of an apothecary, where he remained eight years. In 1821, he became a student in the University of Berlin, and in the following year published his first paper, in which he described the galvanometer, since, in its improved form, so necessary an instrument of physical research. The true work of his life began in 1824, when he issued the first number of the "Annalen der Physik und Chemie" as a continuation of the "Annalen der Physik" of Gilbert. During fifty-three years, Poggendorff directed the publication of the "Annalen," — the noblest scientific periodical which has ever appeared, the one work which is indispensable to the student of physical science. Every important memoir in any department of physics appeared in this journal. Almost the whole scientific life of Berzelius,

Faraday, Melloni, Magnus, the two Roses, Mitscherlich, Regnault, and a host of others, is written in its pages, and a large proportion of the translations from foreign languages were the work of the editor alone. After fifty years of his unassuming labor, Poggendorff's friends united in contributing to a "Jubelband," or jubilee volume, in honor of the anniversary of his connection with the "Annalen;" and a goodly tome filled with original memoirs marked the beginning of the second half-century of his life-work. A short time before his death, Poggendorff sought to give the "Annalen" a still wider range of usefulness by the occasional publication of "Beiblätter," or supplements, containing brief abstracts of the work of foreign investigators. The first number of this supplement appeared only a few days before his death. It might well be thought that the superintendence of the "Annalen" would be work enough for one man. But Poggendorff found time for original researches in several branches of physics, chiefly in electricity and magnetism. We owe to him the invention of the method of measuring small angular variations by means of a plane-mirror telescope and scale, now in constant use. To chemistry he contributed the method of indirect analysis, which is frequently of great value. The list of his published papers embraces more than one hundred and thirty titles. In 1863, he published, in two large volumes, the well-known "Biographisch-literarisches Handwörterbuch zur Geschichte der exacten Wissenchaften," — the worthy forerunner of the noble work of the Royal Society, and in itself a monument of careful labor. In Berlin, Poggendorff was surrounded by a circle of warmly attached friends. He was himself the type of the German scientist. Of unusual discrimination and critical ability, — laborious, patient, untiring, — he worked in his own vocation for nearly sixty years "without haste and without rest." Personally, he was kindly, genial, and hospitable, perfectly free from ostentation, with the heartiest sympathy for the student of science, and the most cordial appreciation of the work of others. On the 24th of January last, in his eighty-first year, he died, leaving a name honored wherever science is honored, cherished and loved by all who knew the man.

KARL ERNST VON BAER.

Karl Ernst Von Baer was born the 29th Feb., 1792, at Piep, the estate of his father in Esthonia, and died at Dorpat, aged eighty-four. It was a long life devoted to intellectual work, and, though it included active periods of travel and exploration, its most memorable events belong to the laboratory and are to be found in the annals of scientific

research during two-thirds of a century. The opening and closing scenes of his life were closely connected; for at Dorpat, in the early days of the University (1810–14), he received his collegiate education and his doctor's diploma, and there he retired to devote the quiet decline of his old age to his favorite studies, interrupted only by his death, Nov. 28, 1876. Although he graduated as a physician, he left the university at twenty-one years of age with a strong bent for natural history, strengthened by the influence of the botanist, Professor Ledebour, and the physiologist, Burdach. But to the naturalist in those days, unless fortune had made him independent, no path was open except that of medicine. The study of disease, with its accompanying branches of comparative anatomy and physiology, was the indirect road to the study of nature. Yet the young Von Baer struggled manfully with his predilection, and on his way to Vienna where he went to acquire practical familiarity with his profession, though keen to observe every thing of interest, he himself tells us that he avoided collections, as he would have done "a consuming fire." At Vienna, he tried, by throwing himself with new ardor into his professional work, to forget his passion for natural history. To this object, however, his excursions in the neighborhood, on which he allowed himself to botanize and geologize a little, were by no means favorable. On one of these rambles, somewhere in the environs of Salzburg, he fell in with Martius, the botanist, and this chance meeting proved a turning point in his career. Martius told him to go and study with Döllinger at Würzburg, and gave him as an introduction a package of mosses to be delivered to him. One of the most pleasing passages in his autobiography is that in which he describes himself as coming full of hope into the presence of the professor; handing the package, and stating at the same time his desire to attend his course on comparative anatomy. "I do not lecture on comparative anatomy this term," answered Döllinger, in the quiet, slow manner peculiar to him, at the same time opening the package and examining the mosses. As the young man stood for a moment silent and bewildered in his disappointment, the professor looked up again and said, "Why lectures? Bring an animal and dissect it here, and then another." The difficulty was solved. The young student appeared the next morning with a case of instruments and a leech purchased at an apothecary's shop. From that time, his table was in the laboratory of Döllinger, who was not slow to recognize in his new pupil a naturalist of the first order. A true teacher, Döllinger was lavish of his intellectual capital, giving to his pupils with generous disregard of his own scientific rights, the results of his original and unpublished investigations. His unselfishness was appre-

ciated by his pupils, and by none more than Von Baer, who speaks of him as his "worthy, well beloved, deeply revered teacher." During his stay at Würzburg, Von Baer became intimate with Pander, then beginning, under the direction of Döllinger and with the assistance of Dalton, the great series of embryological investigations, in which Von Baer afterward took so prominent a part, and which has made the names of all three, Döllinger, Von Baer, and Pander, synonymous with the science of embryology. Pander's embryology of the chick first gave the clew to Kaspar Friedrich Wolff's descriptions, and the connection of Von Baer with Pander's researches led him to investigations long unnoticed, and barely appreciated even now in their full value and significance, though they have gained for him the title of the founder of modern embryology.

The doubts as to his future career were happily solved at the close of his two years' residence in Würzburg by a letter from Burdach his former professor in Dorpat, offering him a place as assistant in the newly founded anatomical department in the University of Königsberg. This he gladly accepted, and, after a winter spent in Berlin in preparation for his new office, we find him established in 1817 at Königsberg. He entered on his duties with energy and success, cheered by seeing his old professor among the regular attendants at his lectures. His knowledge of the lower animals was extensive; and, though compelled to give his time chiefly to human anatomy, he made a series of preparations intended as the basis of a small museum. In 1819, through the influence of his colleague, Schweigger, he was appointed professor of zoölogy, with an additional salary of 300 thalers, and the understanding that he was to build up a great museum for the University of Königsberg. With his prospects thus improved, he now married Fräulein von Meden, and felt himself bound by new ties to Königsberg, where he remained till 1829. It was a brilliant period in the life of the university when, beside Von Baer, its faculty could boast of men like Schweigger, Schubert, Jacobi, Bessel, Struve, Lobech and the older Hagen. On Schweigger's death, Von Baer was made regular professor of natural history and zoölogy, with a considerable increase of salary, virtually diminished, however, by the necessity of purchasing books for his department, which the university found itself too poor to supply. His professional duties, combining instruction to the medical and zoölogical students with the care of the museum, were now very onerous. With all his energy and devotion, the museum moved far too slowly for his zeal. Occasionally, he was cheered by donations or by collections contributed from distant lands; and he succeeded in enlisting the sym-

pathies of the minister of public instruction and of the professors of the university. But the very modest allowance he received from the university, spite of occasional aid from outside, forced upon him a discouraging economy in the administration of the museum.

In the midst of all these professional duties, he found time for his special studies in geology, anthropology, and anatomy, and continued his systematic observations in embryology. As early as 1818, he had laid the foundation of his great generalization on the distinct modes of development for the four great branches of the animal kingdom, and in 1826 he published, in Burdach's "Physiology," his embryology of the chick and frog. Chiefly attracted by the development of Vertebrates, he first showed the identity of the mammalian egg, including that of man, with the egg of fishes. These results first appeared in the memorable treatise entitled "De Ovi Mammalium et Hominis Genesi," in 1827. It was in advance of the time, and, with the exception of a sneering comment on the egg found by a great man in the ovary of a woman, was hardly mentioned in the annual scientific reports of the day. The light thrown upon this paper by the writings of a later set of embryologists, Rathke, Bischoff, and Kölliker, first made known the vast importance of the theory of embryonic layers announced by Von Baer. It was followed in 1828 by the first volume of his "Entwickelungsgeschichte;" but it was only in 1831 that Von Baer was rewarded by the French Academy with one of its prizes. The English were even slower to recognize his merit, and the first English translation of the most important biological work of the century, the "Entwickelungsgeschichte" appeared only in 1855.

In 1829, Von Baer was invited to take charge of the zoölogical department in the Academy of St. Petersburg. He had, however, a certain distrust of the position from the long-continued delay in the publication of the great work of Pallas. On this account, although they were inclined to grant all he asked, he decided to remain at Königsberg, making it a condition, however, that he should have certain facilities for his embryological investigations. He now devoted himself especially to his investigations on the special modes of development characterizing the principal types of the animal kingdom, the results of which were embodied in the second volume of his "Entwickelungsgeschichte." During the second period of his Königsberg life, the social and political circumstances became less favorable to his aims, and in 1832 he renewed his negotiations with St. Petersburg; this time with a different result, for in 1834 we find him established there. He now entered on a life of greater activity and variety than

any he had hitherto known. Under the auspices of the academy, he made a number of journeys first to Lapland and Nova Zembla, and later in the interests of the fisheries to the Volga, Lake Peipus, and the Caspian Sea. He published full reports of all these explorations, and remained a most active member of the Academy till 1862, when he was made an honorary member.

Von Baer was a strong believer in development, but an uncompromising opponent of Darwinism, one of his last papers being a protest against the assumed descent of Vertebrates from Ascidians. The breadth of his culture, his great learning, his native simplicity of character, are nowhere better shown than in the volumes of his collected addresses, more popular essays and lectures. While, however, he inclines to make knowledge accessible to all, he speaks with quiet contempt of the dilettante science, Phytogeny, — if we may so call it, — which threatens to drown all serious investigations under its fantastic theories.

A few men in every century leave the tide line of human knowledge higher than they found it. Von Baer was one of these. Less brilliant perhaps than Cuvier, he is equally identified with the theory of types; and the fame of Von Baer may even outrun that of his great contemporary, since to embryology rather than to any other science we may look for the elucidation of the prominent biological problems of the day.

Since the last Report, the Academy has received an accession of eighteen new members: three Fellows, A. Graham Bell, B. H. Nash, W. E. Story; seven Associate Fellows, William Ferrel, J. L. Diman, Thomas Hill, George Mary Searle, Henry Larcom Abbott, Nathaniel Holmes, Richard Saltonstall Greenough; eight Foreign Honorary Members, Ernst Curtius, F. A. A. Mignet, James Paget, Mark Pattison, H. C. Rawlinson, A. P. Stanley, Alfred Tennyson, Viollet-Le-Duc. On the other hand, by removal from the State or by resignation, the following Fellows have abandoned their membership: Francis Bowen, Edward C. Cabot, William Ferrel, George S. Hillard, Ira Remson, William E. Story. The list of the Academy corrected to June, 1877, is hereto added. It includes 181 Fellows, 96 Associate Fellows, and 72 Foreign Honorary Members.

LIST

OF THE FELLOWS AND FOREIGN HONORARY MEMBERS.

JUNE 14, 1876.

FELLOWS. — 181.

(Number limited to two hundred.)

CLASS I. — *Mathematical and Physical Sciences.* — 58.

SECTION I. — 7.

Mathematics.

Ezekiel B. Elliott,	Washington.
Benjamin A. Gould,	Cordoba.
Gustavus Hay,	Boston.
Benjamin Peirce,	Cambridge.
James M. Peirce,	Cambridge.
John D. Runkle,	Boston.
Edwin P. Seaver,	Boston.

SECTION II. — 8.

Practical Astronomy and Geodesy.

J. Ingersoll Bowditch,	Boston.
Alvan Clark,	Cambridgeport.
Henry Mitchell,	Roxbury.
Robert Treat Paine,	Boston.
E. C. Pickering,	Cambridge.
William A. Rogers,	Cambridge.
L. Trouvelot,	Cambridge.
Henry L. Whiting,	Boston.

SECTION III. — 26.

Physics and Chemistry.

John Bacon,	Boston.
A. Graham Bell,	Boston.
John H. Blake,	Boston.
Thos. Edwards Clark,	Williamstown.
W. J. Clark,	Amherst.
Josiah P. Cooke, Jr.,	Cambridge.
James M. Crafts,	Boston.
William P. Dexter,	Roxbury.
Charles W. Eliot,	Cambridge.
Moses G. Farmer,	Newport.
Wolcott Gibbs,	Boston.
Augustus A. Hayes,	Brookline.
Henry B. Hill,	Cambridge.
Eben N. Horsford,	Cambridge.
T. Sterry Hunt,	Boston.
Charles L. Jackson,	Cambridge.
Joseph Lovering,	Cambridge.
John M. Merrick,	Boston.
William R. Nichols,	Boston.
John M. Ordway,	Boston.
Edward S. Ritchie,	Boston.
S. P. Sharples,	Cambridge.
Frank H. Storer,	Jamaica Plain.
John Trowbridge,	Cambridge.
Cyrus M. Warren,	Brookline.
Charles H. Wing,	Boston.

SECTION IV. — 17.

Technology and Engineering.

G. R. Baldwin,	Woburn.
John M. Batchelder,	Cambridge.
C. O. Boutelle,	Washington.
Henry L. Eustis,	Cambridge.
James B. Francis,	Lowell.
John B. Henck,	Boston.
John C. Lee,	Salem.
William R. Lee,	Roxbury.
Hiram F. Mills,	Lawrence.
Alfred P. Rockwell,	Boston.
John Rodgers,	Washington.
Stephen P. Ruggles,	Boston.
Charles S. Storrow,	Boston.
John H. Temple,	W. Roxbury.
William R. Ware,	Boston.
William Watson,	Boston.
Morrill Wyman,	Cambridge.

Class II. — *Natural and Physiological Sciences.* — 66.

Section I. — 11.

Geology, Mineralogy, and Physics of the Globe.

Thomas T. Bouvé,	Boston.
William T. Brigham,	Boston.
Algernon Coolidge,	Boston.
John L. Hayes,	Cambridge.
Charles T. Jackson,	Boston.
Jules Marcou,	Cambridge.
Raphael Pumpelly,	Boston.
William B. Rogers,	Boston.
Nathaniel S. Shaler,	Cambridge.
Charles U. Shepard,	Amherst.
Josiah D. Whitney,	Cambridge.

Section II. — 10.

Botany.

Jacob Bigelow,	Boston.
George B. Emerson,	Boston.
William G. Farlow,	Boston.
George L. Goodale,	Cambridge.
Asa Gray,	Cambridge.
H. H. Hunnewell,	Wellesley.
John A. Lowell,	Boston.
Chas. J. Sprague,	Boston.
Edward Tuckerman,	Amherst.
Sereno Watson,	Cambridge.

Section III. — 26.

Zoölogy and Physiology.

Alex. E. R. Agassiz,	Cambridge.
J. A. Allen,	Cambridge.
Robert Amory,	Brookline.
Nath. E. Atwood,	Provincetown.
James M. Barnard,	Boston.
Henry P. Bowditch,	Boston.
Thomas M. Brewer,	Boston.
Samuel Cabot,	Boston.
John Dean,	Waltham.
Silas Durkee,	Boston.
Herrmann A. Hagen,	Cambridge.
C. E. Hamlin,	Cambridge.
Alpheus Hyatt,	Cambridge.
Wm. James,	Cambridge.
Samuel Kneeland,	Boston.
Theodore Lyman,	Boston.
John McCrady,	Cambridge.
Edward S. Morse,	Salem.
Alpheus S. Packard, Jr.,	Salem.
Charles Pickering,	Boston.
L. F. Pourtales,	Cambridge.
Frederic W. Putnam,	Cambridge.
Samuel H. Scudder,	Cambridge.
D. Humphreys Storer,	Boston.
Henry Wheatland,	Salem.
James C. White,	Boston.

Section IV. — 19.

Medicine and Surgery.

Samuel L. Abbot,	Boston.
Henry J. Bigelow,	Boston.
Henry I. Bowditch,	Boston.
Edward H. Clarke,	Boston.
Benjamin E. Cotting,	Roxbury.
Thomas Dwight,	Boston.
Robert T. Edes,	Roxbury.
Calvin Ellis,	Boston.
Richard M. Hodges,	Boston.
Oliver W. Holmes,	Boston.
R. W. Hooper,	Boston.
John B. S. Jackson,	Boston.
Edward Jarvis,	Dorchester.
Edward Reynolds,	Boston.
Horatio R. Storer,	Boston.
John E. Tyler,	Boston.
J. Baxter Upham,	Boston.
Charles E. Ware,	Boston.
Henry W. Williams,	Boston.

Class III.—*Moral and Political Sciences.*—57.

Section I.—15.

Philosophy and Jurisprudence.

George Bemis,	Boston.
George T Bigelow,	Boston.
Richard H. Dana, Jr.,	Boston.
C. C. Everett,	Cambridge.
Horace Gray,	Boston.
Frederic H. Hedge,	Cambridge.
L. P. Hickok,	Northampton.
Ebenezer R. Hoar,	Concord.
Mark Hopkins,	Williamstown.
C. C. Langdell,	Cambridge.
Henry W. Paine,	Cambridge.
Theophilus Parsons,	Cambridge.
Charles S. Peirce,	Washington.
Benjamin F. Thomas,	Boston.
Francis Wharton,	Cambridge.

Section II.—12.

Philology and Archæology.

Ezra Abbot,	Cambridge.
William P. Atkinson,	Boston.
H. G. Denny,	Boston.
Epes S. Dixwell,	Cambridge.
William Everett,	Cambridge.
William W. Goodwin,	Cambridge.
Ephraim W. Gurney,	Cambridge.
Bennett H. Nash,	Boston.
Chandler Robbins,	Boston.
John L. Sibley,	Cambridge.
E. A. Sophocles,	Cambridge.
Edward J. Young,	Cambridge.

Section III.—16.

Political Economy and History.

Chas. F. Adams, Jr.,	Quincy.
Henry Adams,	Boston.
Erastus B. Bigelow,	Boston.
Caleb Cushing,	Newburyport.
Charles Deane,	Cambridge.
Charles F. Dunbar,	Cambridge.
Samuel Eliot,	Boston.
George E. Ellis,	Boston.
E. L. Godkin,	Cambridge.
William Gray,	Boston.
Edward Everett Hale,	Boston.
Francis Parkman,	Brookline.
A. P. Peabody,	Cambridge.
Nathaniel Thayer,	Boston.
Henry W. Torrey,	Cambridge.
Robert C. Winthrop,	Boston.

Section IV.—14.

Literature and the Fine Arts.

Charles F. Adams,	Boston.
William T. Andrews,	Boston.
George S. Boutwell,	Groton.
J. Elliot Cabot,	Brookline.
Francis J. Child,	Cambridge.
Ralph Waldo Emerson,	Concord.
John C. Gray,	Cambridge.
Henry W. Longfellow,	Cambridge.
James Russell Lowell,	Cambridge.
Charles Eliot Norton,	Cambridge.
John K. Paine,	Cambridge.
Thomas W. Parsons,	Wellesley.
Charles C. Perkins,	Boston.
John G. Whittier,	Amesbury.

ASSOCIATE FELLOWS. — 96.

(Number limited to one hundred.)

Class I. — *Mathematical and Physical Sciences.* — 36.

Section I. — 7.

Mathematics.

Charles Avery,	Clinton, N.Y.
William Ferrel,	Washington.
Thomas Hill,	Portland, Me.
Simon Newcomb,	Washington, D.C.
H. A. Newton,	New Haven, Conn.
James E. Oliver,	Ithaca, N.Y.
T.H. Safford,	Williamstown, Mass.

Section II. — 11.

Practical Astronomy and Geodesy.

S. Alexander,	Princeton, N.J.
W.H.C. Bartlett,	West Point, N.Y.
J. H. C. Coffin,	Washington, D.C.
Wm. H. Emory,	Washington, D.C.
J. E. Hilgard,	Washington, D.C.
George W. Hill,	Nyack, N.Y.
Elias Loomis,	New Haven, Conn.
Maria Mitchell,	Poughkeepsie, N.Y.
C. H. F. Peters,	Clinton, N.Y.
George M. Searle,	New York.
Chas. A. Young,	Hanover, N.H.

Section III. — 12.

Physics and Chemistry.

F. A. P. Barnard,	New York.
John W. Draper,	New York.
Joseph Henry,	Washington, D.C.
S. W. Johnson,	New Haven, Conn.
John Le Conte,	San Francisco, Cal.
A. M. Mayer,	Hoboken, N.J.
W. A. Norton,	New Haven, Conn.
Ogden N. Rood,	New York.
H. A. Rowland,	Baltimore.
L.M. Rutherfurd,	New York.
Benj. Silliman,	New Haven, Conn.
J. L. Smith,	Louisville, Ky.

Section IV. — 6.

Technology and Engineering.

Henry L. Abbot,	New York.
R. Delafield,	Washington, D.C.
A.A. Humphreys,	Washington, D.C.
Wm. Sellers,	Philadelphia.
George Talcott,	Albany, N.Y.
W.P. Trowbridge,	New Haven, Conn.

Class II. — *Natural and Physiological Sciences.* — 29.

Section I. — 13.

Geology, Mineralogy, and Physics of the Globe.

George J. Brush,	New Haven, Conn.
James D. Dana,	New Haven, Conn.
J. W. Dawson,	Montreal, Canada.
Edward Desor,	Neufchâtel, Switz.
J. C. Fremont,	New York.
F. A. Genth,	Philadelphia.
Arnold Guyot,	Princeton, N.J.
James Hall,	Albany, N.Y.
F. S. Holmes,	Charleston, S.C.
Joseph Leconte,	San Francisco.
J. Peter Lesley,	Philadelphia.
Wm. T. Roepper,	Bethlehem, Pa.
Geo. C. Swallow,	Columbia, Mo.

SECTION II. — 4.

Botany.

A. W. Chapman, Apalachicola, Fla.
G. Engelmann, St. Louis, Mo.
Leo Lesquereux, Columbus, Ohio.
S. T. Olney, Providence, R.I.

SECTION III. — 9.

Zoölogy and Physiology.

S. F. Baird, Washington, D.C.
C. E. Brown-Séquard, London.
J. C. Dalton, New York.
J. P. Kirtland, Cleveland, Ohi
J. L. LeConte, Philadelphia.
Joseph Leidy, Philadelphia.
O. C. Marsh, New Haven, C
S. Weir Mitchell, Philadelphia.
St. Julien Ravenel, Charleston,

SECTION IV. — 3.

Medicine and Surgery.

W. A. Hammond, New York.
Isaac Hays, Philadelphia.
George B. Wood, Philadelphia.

CLASS III. — *Moral and Political Sciences.* — 31.

SECTION I. — 7.

Philosophy and Jurisprudence.

D. R. Goodwin, Philadelphia.
R. G. Hazard, Peacedale, R.I.
Nathaniel Holmes, St. Louis, Mo.
James McCosh, Princeton.
Noah Porter, New Haven, Conn.
Isaac Ray, Philadelphia.
Jeremiah Smith, Dover, N.H.

SECTION II. — 11.

Philology and Archæology.

A. N. Arnold, Hamilton, N.Y.
D. C. Gilman, Baltimore.
S. S. Haldeman, Columbia, Pa.
A. C. Kendrick, Rochester, N.Y.
Geo. P. Marsh, Rome.
L. H. Morgan, Rochester, N.Y.
A. S. Packard, Brunswick, Me.
E. E. Salisbury, New Haven, Conn.
A. D. White, Ithaca, N.Y.
W. D. Whitney, New Haven, C
T. D. Woolsey, New Haven, C

SECTION III. — 8.

Political Economy and Histor

S. G. Arnold, Newport, R.I.
Geo. Bancroft, Washington.
S. G. Brown, Clinton, N.Y.
Henry C. Carey, Philadelphia.
J. L. Diman, Providence, R
Henry C. Lea, Philadelphia.
Barnas Sears, Scranton, Va.
J. H. Trumbull, Hartford.

SECTION IV. — 5.

Literature and the Fine Arts

James B. Angell, Ann Arbor, M
Wm. C. Bryant, New York.
F. E. Church, New York.
R. S. Greenough, Florence.
Wm. W. Story, Rome.

FOREIGN HONORARY MEMBERS.—72.

(Appointed as vacancies occur.)

Class I.—*Mathematical and Physical Sciences.*—25.

Section I.—8.

Mathematics.

John C. Adams,	Cambridge.
Sir George B. Airy,	Greenwich.
Brioschi,	Milan.
Arthur Cayley,	Cambridge.
Chasles,	Paris.
Le Verrier,	Paris.
Liouville,	Paris.
J. J. Sylvester,	Woolwich.

Section II.—4.

Practical Astronomy and Geodesy.

Döllen,	Pulkowa.
H. A. E. A. Faye,	Paris.
Peters,	Altona.
Otto Struve,	Pulkowa.

Section III.—11.

Physics and Chemistry.

R. Bunsen,	Heidelberg.
E. Chevreul,	Paris.
J. Dumas,	Paris.
H. Helmholtz,	Berlin.
A. W. Hofmann,	Berlin.
G. Kirchhoff,	Berlin.
J. C. Maxwell,	Cambridge.
V. Regnault,	Paris.
Balfour Stewart,	Manchester.
G. G. Stokes,	Cambridge.
F. Wöhler,	Göttingen.

Section IV.—2.

Technology and Engineering.

R. Clausius,	Bonn.
Sir Wm. Thomson,	Glasgow.

Class II.—*Natural and Physiological Sciences.*—25.

Section I.—8.

Geology, Mineralogy, and Physics of the Globe.

Barrande,	Prague.
Charles Darwin,	Beckenham.
H. W. Dove,	Berlin.
James Prescott Joule,	Manchester.
W. H. Miller,	Cambridge.
C. F. Rammelsberg,	Berlin.
A. C. Ramsay,	London.
Sir Edward Sabine,	London.

Section II.—6.

Botany.

George Bentham,	London.
Decaisne,	Paris.
Alphonse de Candolle,	Geneva.
Elias Fries,	Upsal.
Oswald Heer,	Zurich.
Joseph Dalton Hooker,	London.

SECTION III. — 8.

Zoölogy and Physiology.

T. L. W. Bischoff,	Munich.
Milne-Edwards,	Paris.
Albrecht Kölliker,	Würzburg.
Rudolph Leuckart,	Leipzig.
Richard Owen,	London.
C. Th. Von Siebold,	Munich.
J. P. Steenstrup,	Copenhagen.
Valentin,	Berne.

SECTION IV. — 3.

Medicine and Surgery.

Sir James Paget,	London.
Rokitansky,	Vienna.
Virchow,	Berlin.

CLASS III. — *Moral and Political Sciences.* — 22.

SECTION I. — 4.

Philosophy and Jurisprudence.

T. C. Bluntschli,	Heidelberg.
Sumner Maine,	London.
James Martineau,	London.
Sclopis di Salerano,	Turin.

SECTION II. — 6.

Philology and Archæology.

Pascual de Gayangos,	Madrid.
Benjamin Jowett,	Oxford.
Sir H. C. Rawlinson,	London.
Lepsius,	Berlin.
Max Müller,	Oxford.
F. Ritschl,	Leipzig.

SECTION III. — 9.

Political Economy and History.

Ernst Curtius,	Berlin.
W. Ewart Gladstone,	London.
Charles Merivale,	Oxford.
F. A. A. Mignet,	Paris.
Mommsen,	Berlin.
Mark Pattison,	Oxford.
Von Ranke,	Berlin.
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